Estimation of Time

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ESTIMATION OF TIME

BY
ROBERT AXEL, Ph.D.

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R. S. WOODWORTH, Editor
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I. INTRODUCTION

While the philosophers have been trying to solve the nature of time, the psychologists have assumed its existence; and with this assumption many of the latter have made various attempts to solve this perplexing problem under experimental conditions. Assuming the existence of time, what conditions influence our estimation of it?

The importance of a careful investigation of this phenomenon can be readily understood when we realize the intimate relationship existing between ability to estimate time and general adaptation. An individual devoid of the time-sense could not exist. "Better late than never" is a proverb which has too many exceptions. The inability to react promptly may mean the loss of a life in many an enterprise. The study of individual differences and the conditions which influence estimation of time is therefore worthy of great labor.

The purpose of the present investigation was primarily to determine (1) the effect of different fillings upon estimation of the duration of time, and (2) how this ability is influenced by age. In regard to technique, the writer is somewhat at variance with previous investigators. In past investigations no serious attempt was made at a rigid classification of the introduction of different fillings. In the present study the writer has ventured to classify the fillings into four main divisions: (1) "estimation," (2) "motor activity," (3) "sensori-motor activity," (4) "mental activity." An explanation of these different types of activity will appear subsequently. With the exception of "estimation," the fillings employed were of such a nature as to demand complete concentration on the part of the subjects. The latter were required to work as quickly and accurately as possible. No fillings such as reading by the experimenter were introduced because of the difficulty in determining the degree of concentration by the subject. In short, the present experiment deals with estimation of time when the individual is working "against time." After working as rapidly and accurately as possible, he then estimates how long he has been engaged in that activity. Does he underestimate or overestimate time when engaged in this type of work?

The influence of age upon estimation of time has received as yet very little attention. The author has attempted to make a thorough investigation of this factor, and it is his hope that the results obtained will act as an impetus toward further investigation in this field.

The author wishes to acknowledge his indebtedness to Professor R. S. Woodworth of Columbia University for his kind assistance with reference to the methodology, and for his many suggestions. To Professor A. T. Poffenberger of Columbia University the writer desires also to acknowledge his gratitude for his kind assistance. The writer wishes to express his thanks to Mr. Louis Marks, formerly Principal of P. S. 64, New York City, for his kind cooperation in the supervision of part of the experiment at his school. Thanks are also due the teachers of P. S. 64 for their kind assistance in the administration of the tests.

II. HISTORICAL SURVEY

There is no dearth of psychological literature dealing with the phenomenon of estimation of time from a theoretical aspect. As William James holds the prevailing opinion among psychologists as regards the estimation of filled and unfilled time, I shall quote verbatim from his Principles of Psychology, Volume I.

"A time filled with varied and interesting experience seems short in passing, but long as we look back. On the other hand, a tract of time empty of experience seems long in passing, but in retrospect short. A day full of excitement, with no pause, is said to pass 'ere we know it.' On the contrary, a day full of waiting, of unsatisfied desire for change, will seem a small eternity. Close your eyes and simply wait to hear somebody tell you that a minute has elapsed. The full length of your leisure with it seems incredible. You engulf yourself into its bowels as into those of that interminable first week of an ocean voyage, and find yourself wondering that history can have overcome many such periods in its course. The odiousness of the whole experience comes from its insipidity; for stimulation is the indispensable requisite for pleasure in an experience, and the feeling of bare time is the least stimulating experience we can have."

Various attempts have been made to study the time-sense under rigid experimental conditions. Three main methods have been most commonly employed:

1. *The Method of Comparison.* Two successive intervals of time are marked off by three clicks and the subject is caused to compare the relative lengths of these time intervals.
2. *The Method of Reproduction.* The subject reproduces a time interval marked off by two clicks.
3. *The Method of Estimation.* The object here is to determine, in terms of conventional units of time, the length of the interval under standard conditions.

The type of method employed depends largely upon the nature of the investigation. Each has its advantages and disadvantages.

The earlier investigators concerned themselves with individual reactions to very small intervals of time, usually not longer than twelve seconds. A great deal of attention was devoted to such phenomena as the Indifference Point (the interval of best judgment), the validity of Weber's Law, fixed or constant periodicity, and the effect of psycho-physically conditioned changes upon the time-sense. The later investigators began where the others left off, and increased the length of the time intervals to a few minutes. Long durations of time are rarely studied because of the extreme tediousness of the work. A group of subjects would not relish the idea of estimating a time interval of five or six hours however enthusiastic the experimenter might be. The more recent studies which will be described presently are mainly concerned with sex differences in estimation of time and the effect of various fillings upon the time-sense.

MacDougall[1] discovered marked sex differences in the estimation of time. The test involved periods of time extending from a quarter of a minute to a minute and a half in duration. The intervals were filled in four ways: (1) the instructor read aloud to the class from a psychological work unfamiliar to its members; (2) the members of the class marked as rapidly as possible all the letter m's in a page of printed text; (3) the class waited in idleness for the period to pass by, refraining as far as possible from counting or other means of recording the lapse of time; (4) each person estimated as accurately as possible the period in question, using whatever method he had personally found most serviceable for the purpose. The nature and extent of the overestimation discovered by MacDougall are indicated by the results presented in the accompanying table, in which plus and minus indicate, respectively, over- and under-estimation of the duration in terms of seconds, and the figures at the top of the columns the series of conditions.

Period, One Minute

Sex	1	2	3	4
Men	+29″	+ 1.3″	+22″	— 3.5″
Women	+66	+22.0	+80	+24.0

From the above results, MacDougall concludes that the tendency toward overestimation is very much stronger in the women than in the men. "In the case of men, keeping tally of the passing seconds results in the elimination of the positive error and the appearance of a slight under-estimation. The women are also markedly less accurate than the men."

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[1] MacDougall, Robert. "Sex Differences in the Sense of Time," Science, N. S., 1904, 19, pp. 707-708.

Yerkes and Urban[2] made a thorough study of the time-sense of 251 males and 274 females. The majority of the males were students in Harvard College, the majority of the females in Radcliffe and Smith Colleges. The remainder of the records were obtained in Ohio State University, Pomona College, and West Chester State Normal School. The males ranged in age from 17 to 23 years, the females from 17 to 20. The fillings employed were: (1) "idleness," (2) "reading," (3) "writing," (4) "estimating."

"During the filling called 'idleness' the subject did not pay special attention to the estimation of the time, but instead permitted his attention to wander.

"During 'reading' the experimenter read aloud to the subjects.

"During 'writing' the subjects wrote from the dictation of the experimenter.

"During 'estimating' the subjects judged the interval as accurately as they could, by whatever method they chose except the use of a timepiece."

Yerkes and Urban summarize their results as follows:

(1) "Intervals of from 18 to 108 seconds are usually slightly under-estimated by men (ages 17 to 23 years), and greatly over-estimated by women (ages 17 to 20 years).

(2) "The time-estimates of women are far more variable than those of men, and on the whole markedly less accurate.

(3) "Both men and women favor estimates which end in 0 or 5, as well as simple fractions of a minute, but the tendency is stronger in women than in men. Over one-third of the estimates reported in this paper were 15 seconds or simple multiples thereof.

(4) "Of the four fillings for the intervals used in the experiments, 'writing' gave the smallest estimates of the intervals, listening to 'reading' next, while 'idleness' and 'estimating' were conditions in which the intervals seemed much longer to both men and women."

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[2] Yerkes and Urban. "Time-Estimation in its Relation to Sex, Age, and Physiological Rhythms," Harvard Psychol. Studies, 1906, 2.

Münsterberg[3] experimented with students of his regular psychology course in Harvard. The object of this experiment was to find the reliability of testimony with regard to "perception of time." The students were asked to give the number of seconds which passed between two loud clicks. Two different intervals of time were employed, namely, 10 seconds and 3 seconds. When the interval was ten seconds, the answers varied between half a second and sixty seconds, a good number judging forty-five seconds as the right time. When the objective time was three seconds, the answers varied between half a second and fifteen seconds. These large fluctuations showed themselves in spite of the fact that the students knew beforehand that they were to estimate the time intervals.

Seashore[4] investigated the time-sense in the public schools and found differences between the fifth- and eighth-grade pupils. He also found the adult to be superior to the child in the eighth grade. The subject was asked to compare two intervals of time which differed in length. He entered his judgments in a table, marking S when the second interval was shorter than the first and L when it was longer. The intervals judged were, however, very minute and no conclusions can be drawn as regards longer time intervals.

Myers[5] obtained rather interesting results in his experiments on time-estimation. Forty men of Juniata College and Academy were given three successive tests for estimating a minute interval of time. In the first test the subject read silently from a certain editorial page and at the end of a minute he was requested to judge how long he had been reading. Then he was given a poem which he was requested to read carefully and to state when he had read one minute. Finally he was told to estimate, while unemployed, a minute from the signal "Go." The average time estimated in the first test was 1 min. 23 sec., m.v. 24.6 sec. In the second test, the average was 44.3 sec., m.v. 12.6 and in the third, 37.9 sec., m.v. 15.7.

The same writer gave a group test to forty-six normal-school girls. He read from the introductory chapter of Creighton's "Logic," presumably to present some facts in logic. At the end of one minute the subjects were asked to write down a "precise estimate" of how long he had read. Then they were asked to estimate the same length of time between the signals "Go" and "Halt." The average estimate for the first test was 1 min. 44 sec., with a m.v. of 44.5 sec.; the second test 1 min. 39.2 sec., m. v. 42.

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[3] Münsterberg, Hugo. "On the Witness Stand," Doubleday, Page & Co., 1913.

[4] Seashore, C. E. "A Survey of Musical Talent in the Public Schools," The Iowa Child Welfare Research Station, Iowa City.

[5] Myers, Garry C. "Incidental Perception," J. of Exp. Psychol., 1916, I, pp. 339-350.

A third experiment was performed by Myers designated to test incidental perception of time. "On Monday following a Saturday evening basketball game 100 students, 68 men and 32 women, who had attended the game, were asked to estimate how long they thought the teams had played before 'time out' was called. At the time referred to, a player had received a rather serious injury, 6 minutes, 15 seconds after the game had started. The average estimate by the men was 10 min., 7 seconds. The average estimate by the women was 14 min., 54 seconds. The women varied more than did the men."

Myers summarizes his results as follows:

"On the average one minute of time was over-estimated by about one half. Six and a quarter minutes was doubled in the estimation of the women and over-estimated by about one-half by the men.

"The estimation of a minute of filled time incidentally perceived was about the same as the estimation of empty time purposely perceived. There was, however, a slight gain for purposive perception of filled time over incidental perception of filled time, yet the gain is surprisingly small.

"Wide individual differences obtained with a m.v. of from one-fourth to almost one-half the average. The women are slightly more variable than the men."

Spencer[6] recommends the method of reproduction in studying estimation of time. He claims that the results obtained by Yerkes and Urban were influenced by conditions which favor estimates ending in 0 and 5. He shows, rather ingeniously, that when this influence is removed the number of correct estimates of the intervals selected by Yerkes and Urban would be considerably increased. Spencer used four intervals, 15, 30, 60, and 100 seconds. The fillings employed were: (1) "estimation"—the subject was instructed to reproduce a given interval marked off by the experimenter by two sharp raps on the table; (2) reading of prose by the experimenter; (3) reading prose by the subject; (4) reading of poetry by the experimenter; (5) reading poetry by the subject, and (6) dictation. The interpolation was used only during the stimulus interval. During the reproduction, the subject indicated the judged interval by starting and stopping a stop-watch. Spencer concludes that,

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[6] Spencer, L. T. "An Experiment in Time Estimation Using Different Interpolations." Amer. J. of Psychol., October, 1921, 32.

(1) "The method of reproduction produces more accurate results than the method of statement in terms of the standard unit.

(2) "While the percentage of correct responses is greater when the method of reproduction is used, the percentage thus obtained (3.88%) is very low and shows that time-estimation is not very accurate.

(3) "All intervals were over-estimated when the method of reproduction was used. If the median is used as the measure of central tendency, the over-estimation of the 60 and 100 sec. intervals is not significant. This is true no matter what interpolations are used.

(4) "Poetry as an interpolation causes the interval to be estimated as longer than an interval with no interpolation (i.e., estimation) or than one with the reading of prose.

(5) "The interval is estimated as longer if the subject reads the prose or the poetry than if the material is read by the experimenter.

(6) "Dictation causes the interval to be estimated as shorter than one with any other of the interpolations used, but not necessarily shorter than the actual interval.

(7) "The results of Yerkes and Urban agree with this study in the comparison of one interpolation with another, as to the effect upon the judgments, although they vary from the present findings in the relation of the judgments of the intervals to the actual intervals."

III. THE PROBLEM

A careful analysis of the works of the latest experimenters on the time-sense discloses the fact that no attempt was made toward a rigid classification of fillings. Obviously, the number of fillings that can be employed in studying this problem is well-nigh infinite. For instance, if the fillings "reading" and "writing" are selected at random in an experiment, a comparison of the results obtained leads to ambiguity of conclusion. There is a vast amount of material that may be used in the "reading" experiment and the same is true of "writing." Hence, a scientific procedure would require the use of the same sort of material in both experiments.

Another method of attacking the problem of estimation of time is to classify the fillings in terms of different levels of human behavior. We know that tapping with the foot or hand involves a type of activity which is quite different from the solution of a problem in the calculus. The neural activity in the latter is decidedly more complex and is the result of the function of the higher nerve centers. In the study of the time-sense these different levels of behavior should be taken into consideration.

The writer had these important facts in mind in the investigation of this problem. An attempt was made to determine the effect of these various levels of behavior upon estimation of time. A classification of these different types of activity was found necessary. The most feasible plan was to arrange the fillings in a certain definite order, beginning with simple motor activity and gradually ascending the scale until the complex reactions were reached. The author's problem has branched out into subsidiary problems which may be stated as follows:

(1) What is the relation between estimation of filled and unfilled time?

(2) What is the relation between estimation of time and level of human behavior?

(3) Are there individual differences in time-estimation?

(4) What is the effect of age upon the time-sense?

(5) What is the relation between quantity of production of work and estimation of time?

IV. METHOD OF PROCEDURE

The investigation of the time-sense was made upon two distinct groups, i.e., (1) college undergraduate and graduate students, and (2) elementary school children.

A. Investigation of the Time-Sense of Graduate and Undergraduate Students.

This portion of the experiment was performed upon 68 students. These comprised 28 male undergraduates of the College of the City of New York, 28 men and women pursuing extension courses in introductory psychology at Columbia University, and 12 male and female graduate students in psychology at the same University. All the subjects but the third group were practically unfamiliar with the subject matter of psychology, having had merely three weeks of instruction in this field. Of the subjects tested, there were 46 men and 22 women, the former ranging in age from 17 to 42 years and the latter from 17 to 50 years. Only 4 of the 68 subjects were above 40 years of age. Sixteen successive intervals of time, ranging from 15 to 30 seconds, were presented for each filling. The ordinary stop-watch measuring fifths of a second was employed in the presentation of the time intervals. The starting and stopping of the watch were accompanied by the commands "Go!" and "Stop!", respectively.

The five fillings employed were (1) "estimation," (2) tapping, (3) cancellation, (4) analogies, and (5) number series completion. Sixteen time-estimates were secured for each filling. Thus 80 reactions were obtained for each individual and 5440 estimates for the entire group. The subjects received ten seconds in which to write their judgments next to corresponding letters on a sheet of paper. The series of time intervals were designated by letters instead of numbers in order that the latter might not influence the individual's judgments.

The experiment was divided into two equal parts. The second portion of the experiment was performed two weeks after the first portion was completed. Each portion consisted of 8 estimates for each filling. The investigation was made during the month of March, 1921. The results of each part of the experiment were given separate statistical treatment in order to determine any possible practise effect resulting from the interval of two weeks between the two portions of the experiment. The subjects might be desirous of testing themselves in the interim to see how proficient they were in estimating time. The writer anticipated possible practise effect and avoided this disturbing factor by mentioning nothing about any further experimentation after the first portion of the investigation was completed. The order of presentation of the fillings and the accompanying time intervals were varied as much as possible for each group, to prevent the "stimulus error" from disturbing the results. A description of the different fillings follows.

1. Estimation—"When I say 'Go', do nothing but wait until I say 'Stop'; and when I say 'Stop' write next to letter—how much time elapsed between the command 'Go' and the command 'Stop.' Use any method you wish of estimating time except the use of a timepiece. Express your answer in terms of seconds. Ready, go."

2. Tapping—Unruled sheets of yellow paper with soft lead pencils of uniform length were provided by the experimenter. The oral instructions were, "When I say 'Go', tap with the point of your pencil on the yellow paper before you as quickly as you can until I say 'Stop.' When I say 'Stop', write next to letter—how long it took you to tap on this paper. Do not tap on the same spot but move your hand along as you continue tapping. Ready, go."

3. Cancellation—The standard test material of the Woodworth and Wells Cancellation Test was used. Oral instructions: "When I say 'Go', cross out every number 5. Begin with the first line. When you have finished one line, go to the next. When I say 'Stop', write next to letter—how long it took you to cross out the 5's. Ready, go."

4. Analogies—100 sets of analogies were collected from 8 different forms of the Army Alpha Tests. The analogies were so arranged as to produce uniform difficulty throughout the test. This was accomplished by mixing the simple and difficult analogies so that every portion of the test contained the same number of simple and difficult sets. This precaution was taken in order that the estimates of the time intervals might not be influenced by lack of uniformity of the difficulty of the mental work. The subjects were provided with more material than they could possibly complete within the prescribed time.

This abundance of work prevented any subject from completing the test too soon and thus making a period of idleness of what was meant to be a period of mental activity. After a certain duration of time, the subjects were interrupted and requested to estimate the length of time of the work-period. This was done for each time interval. The experimenter read aloud the written instructions as they appear in the Army Alpha Manual. In presenting the written analogies, a slight modification in type of print was made. In mimeographing the test material it was found impossible to make the choice words darker than the first three terms of each set of analogies. These choice words were therefore typed in capitals for the purpose of discrimination. Oral instructions: "In each of the lines below, the first two words are related to each other in some way. What you are to do in each line is to see what the relation is between the first two words, and underline the word in capitals that is related in the same way to the third word. Begin with the first one and mark as many sets as you can before time is called. When time is called, write next to letter—how long it took you to mark these sets. Ready, go."

5. Number Series Completion—28 of the most difficult series were selected from the various forms of the Army Alpha Completion Tests and were mixed up to produce uniform difficulty. The experimenter read aloud the written instructions from the Army Alpha Manual with a slight modification to serve the purpose of the experiment. Oral instructions: "Look at each row of numbers below, and on the two broken lines write the two numbers that should come next. (Illustrations of the sample completions were included.) When I say 'Go', do as many sets as you can until I say 'Stop.' When the command 'Stop' is given, write next to letter......how long it took you to do these sets. Ready, go."

B. Investigation of the Time-Sense of Elementary School Children.

This group comprised 792 boys of Public School 64, located on the lower east side of Manhattan, New York City. The subjects tested were of school grades ranging from third year to eighth year. In this school there are special classes for boys of marked inferior and superior mentality. These, however, were not included in this investigation. Only those boys pursuing the regular school curriculum were tested. The results of 30 of these boys were discarded due to inability to follow instructions. This was found to be the result of language difficulty. The utmost precaution was taken to secure uniform procedure in the various school grades. Also, a great effort was made by the investigator to obtain clear comprehension by the subjects of what was to be done. The time intervals employed were 20 seconds and 40 seconds, respectively. For each time interval 4 different fillings were used. The consultation of a timepiece was strictly forbidden throughout the experiment. In each class the official teacher served as assistant supervisor to the examiner. All tests were administered by the writer. The subjects were tactfully urged to try their utmost throughout the test and to refrain from glancing at their neighbors' papers. They were given 10 seconds in which to write their estimates of the time intervals at the end of each filling. No special method was suggested by the experimenter as to how the subjects should determine their judgments. They were requested to work as rapidly and accurately as possible when the command "Go" was given, and to write the estimate upon the command "Stop." The test material was properly arranged and fastened together for each subject.

The order of presentation of the tests was the same for each grade. This uniformity of presentation was necessary for the determination of the various age norms. However, the order of presentation was varied among the different groups comprising each grade so that the effect of the different fillings upon estimation of time could also be determined. The latter procedure was necessary to avoid the "stimulus error." None but the examiner was aware of the exact time intervals, which were marked off by the use of a stop-watch. The teachers in the respective classes were cautioned not to disclose the real nature of the experiment to any other teacher or pupil. Each teacher, however, was assured that the results of the experiment would cause no reflection upon her teaching ability. The experiment was performed on two successive days, June 20 and 21, 1921. Approximately one-half of the number of subjects of each grade were tested each day and their results were compared with those of subjects tested the following day. No significant difference appeared. This precaution was taken to safeguard against any practise effect which might result when communication between the pupils was made possible after school hours.

The following procedure was strictly adhered to in presenting the fillings with the accompanying time intervals:

Preliminary Instructions—"This is a test to see how well you can tell time and also how well you can answer questions. You are not expected to tell time exactly but do the best you can. Be sure to label your answers. If it takes you 3 hours to do something, your answer should be 3 *hours*. If it takes you 14 minutes to do some work, your answer should be 14 *minutes*. If your answer is 12 seconds, write 12 *seconds;* and if it is 2 days, write 2*days*. Remember, be sure to label your answer."

1. Estimation—"Listen carefully. When I say 'Go' do nothing but wait until I say 'Stop,' and when I say 'Stop,' write on the first line of the yellow paper on your desk how long I have kept you waiting. Ready, go."

2. Writing I's—Sheets of ruled yellow paper with soft pencils of uniform length were here employed. The oral instructions were, "When I say 'Go,' write as many i's as you can until I say 'Stop.' Do not dot the i's. When I say 'Stop,' be sure to stop at once and to write on the line just below the last 'i' how long it took you to write these i's. Remember to label your answer. Ready, go." The examiner illustrated on the blackboard the exact manner in which to write the i's in order to avoid confusion on the part of the subjects.

3. Cancellation—Each subject was provided with the standard test material used in the Woodworth and Wells Cancellation Test. The oral instructions were, "When I say 'Go,' cross out every number 5. Begin with the first line. When you have finished one line go to the next line. When I say 'Stop,' write at the top of your paper how long it took you to cross out the 5's. Be sure to label your answer. Ready, go." The examiner illustrated on the blackboard the standard method of crossing out the number 5.

4. Constant Increments—The standard test material was employed. The oral instructions were, "When I say 'Go,' add 7 to each number on your paper. Do not work out the example on your paper. This is 'mental arithmetic' and not 'written arithmetic.' Put down the answer to the right of each number on your paper. When I say 'Stop,' write at the top of your paper how long it took you to add 7 to these numbers. Ready,

go." The method of writing the answer was again illustrated on the blackboard.

CLASSIFICATION OF FILLINGS

I. Investigation of College and University Students		II. Investigation of Elementary School Children	
Class	*Type of Filling*	*Class*	*Type of Filling*
A. Unfilled Time	Estimation	A. Unfilled Time	Estimation
B. Motor Activity	Tapping	B. Motor Activity	Writing i's
C. Sensori-Motor Activity	Cancelling 5's	C. Sensori-Motor Activity	Cancelling 5's
D. Mental Activity	Analogies and Number Series Completion	D. Mental Activity	Adding 7.

V. RESULTS

A. INVESTIGATION OF GRADUATE AND UNDERGRADUATE STUDENTS

1. *Frequency of Occurrence of Certain Numerals as Final Digits of the Judgments*

A detailed study of the judgments of the time intervals, 15 to 30 seconds, conditioned by the five different fillings, reveals some interesting facts. Table I renders a complete analysis of these judgments with reference to the character of the final digits. In the first column are entered the final digits of the judgments. The five succeeding columns contain the frequencies of these judgments conditioned by the fillings Estimation, Tapping, Cancellation, Analogies, and Number Series Completion. The next column designated by the symbol Σ gives the total frequencies based on 5440 responses. The last column, headed by "% total", lists the value of the results in terms of the total number of judgments (5440). This column is designated by "% total" to distinguish it from the rows designated by "%." The latter give the percentages of the frequencies for each filling and the values are determined by dividing the frequency by 1088, which is the number of judgments for each filling.

A survey of the last column immediately discloses the fact that there is a tendency for certain final digits of the judgments to appear more frequently than others. The final digit 0 occurs in 42.4% of the judgments; the final digit 5 in 29.0% of the total number of judgments; all other digits, combined, in only 28.6% of the responses. If no influence were at work, the probability of the occurrence of any final digit would be 1/10, there being 10 possible final digits. We would therefore expect the last digits 0 and 5 to occur in 20% of the judgments, and the remaining digits in 80% of the cases.

It is necessary to ascertain the reliability of the percentage frequency of occurrence of the numerals 0 and 5 as final digits of the judgments. It is a known fact that the theoretical probability of a certain occurrence is influenced by the number of observations. The Standard Error (S. E.) may be determined for this theoretical probability by the use of the following formula:

$$S.E. = \sqrt{\frac{p\,q}{n}}$$ [1]

where p is the proportion of successes and q the proportion of failures for n observations. Here the proportion of successes represents the percentage frequency of occurrence of the final digits 0 and 5, respectively. Thus, we find that the S. E. of the theoretical probability of the occurrence of any final digit is 0.004. Comparing the S. E. of this theoretical probability with the observed difference of 0.324 (42.4% — 10.%), we find that the obtained percentage frequency of occurrence of

TABLE I

FREQUENCY OF OCCURRENCE OF CERTAIN NUMERALS AS FINAL DIGITS OF THE JUDGMENTS

COMBINED RESULTS FOR ALL MALES AND FEMALES

	Estimation	*Tapping*	*Cancellation*	*Analogies*	*Completion*	Σ	*% Total*
Final Digit 0	461	457	433	472	486	2309	42.4
%	42.3	42.0	39.8	43.4	44.6		
Final Digit 5	259	299	332	352	339	1581	29.0
%	23.8	27.5	30.5	32.3	31.1		
Final Digits 0 and 5	720	756	765	824	825	3890	71.4
%	66.1	69.5	70.3	75.7	75.7		
Even Numbers	682	680	651	653	658	3324	61.1
%	62.7	62.5	59.9	60.2	60.5		
Odd Numbers	406	408	437	435	430	2116	38.9
%	37.3	37.5	40.1	39.8	39.5		
Even Numbers not ending in 0	221	223	218	181	172	1015	18.7
%	20.4	20.5	20.1	16.8	15.9		
Odd Numbers not ending in 5	147	109	105	83	91	535	9.9
%	13.5	10.0	9.6	7.5	8.4		
Judgments not ending in 0 or 5	368	332	323	264	263	1550	28.6
%	33.9	30.5	29.7	24.3	24.3		

List of abbreviations:

Σ designates the sum of the judgments of each row of the table with reference to a particular final digit.

% refers to the value of the result in question in terms of the number of judgments for each filling.

% Total refers to the value of the result in question in terms of the total number of judgments.

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[1] Yule, G. Udny. "An Introduction to the Theory of Statistics," Charles Griffin and Company, Limited, 1919.

the numeral 0 as a final digit is very reliable. Similarly, for the final digit 5, the S. E. of the theoretical probability is 0.004 as compared with an observed difference of 0.19 (29.0% — 10.%).

That the difference between the frequency of occurrence of 0 and 5 as final digits is a real one and not due to errors of sampling can be determined by calculating the Standard Deviation of the difference (S. E.). According to G. Udny Yule,

$$\text{S. E.} = \sqrt{p_0 q_0} \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

where $p_0 = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$, $q_0 = 1 - p_0$, p_1 and p_2 the percentage frequencies of occurrence of 0 and 5 as final digits, respectively, and n_1 and n_2 the total number of observations corresponding to the digits 0 and 5.

Thus the S. E. between the frequencies of occurrence of 0 and 5 as final digits is found to be 0.91% as compared with an obtained difference of 13.4% (42.4% — 29.0%). Since the observed difference in frequency of occurrence of the final digits 0 and 5 is more than 14 times as large as its S. E., the difference is very reliable.

We also find in Table I that 61.1% of the judgments are even numbers while only 38.9% are odd numbers. Since the influence of the final digits 0 and 5 greatly affects judgment of these time intervals, it is best to eliminate this influence by subtracting the percentage of judgments with final digits 0 and 5 from the total frequencies of even and odd numbers. After subtraction of judgments ending in 0 and 5, there remain 1550 judgments, of which 1015 are even numbers and 535 are odd numbers. The probability, therefore, of the judgments being even numbers is 0.655 and the probability of the occurrence of odd numbers is 0.345 (not included in Table I). Computing the S. E. of the difference between the two probabilities we obtain 0.018 as compared with the observed difference of 0.310 (0.655 — 0.345). The difference between the probabilities of the judgments is therefore reliable and we can safely conclude that even numbers appear more often than odd numbers in the judgment of the intervals selected.

These results agree, in general, with those obtained by Yerkes and Urban[2]. They found that when the number of judgments ending in 0 and 5 is subtracted from the total number of judgments the probability of even judgments is

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[2] Yerkes and Urban. Op. cit.

0.581 for males and 0.625 for females. Our results show a probability of 0.655. Yerkes and Urban also found the probability of 0 and 5 to be 0.659 for males and 0.816 for females as compared with our calculated probability of 0.714 (0.424 + 0.29). It must be remembered, however, that our results are a composite of those for males and females and that the fillings employed are not the same as in the experiment of Yerkes and Urban. In general, the characteristic frequency of occurrence of judgments ending in 0 and 5 and that of even and odd numbers seems to prevail whatever fillings are employed during time intervals.

Examination of Table I shows at once that the frequency of occurrence of 0 and 5 as final digits depends upon how the time intervals have been filled. Of 1088 judgments for each filling, Estimation gives 720 (66.1%) occurrences of 0 and 5, Tapping 756 (69.5%), Cancellation 765 (70.3%), Analogies 824 (75.7%), and Completion 825 (75.7%). It is, however, necessary to determine the reliability of the difference in frequency of occurrence of the judgments ending in 0 and 5 due to the various fillings. Table II gives these obtained differences when the effects of any two fillings are compared, each difference being accompanied by its S. E. Table II describes the following facts: (1) filled time as evidenced by Tapping, Cancellation, Analogies, and Completion, causes a greater per-

TABLE II

DIFFERENCES AND THEIR S. E.'S BETWEEN PERCENTAGE FREQUENCIES OF OCCURRENCE OF THE FINAL DIGITS 0 AND 5 WHEN A COMPARISON OF FILLINGS IS MADE. COMBINED RESULTS FOR MALES AND FEMALES

N = 1088

Compared Fillings	*Difference*	*S. E. diff.*
Tapping and Estimation	+3.4%	2.00%
Cancellation and Estimation	+4.2	2.00
Analogies and Estimation	+9.6	1.95
Completion and Estimation	+9.6	1.95
Cancellation and Tapping	+0.8	1.97
Analogies and Tapping	+6.2	1.92
Completion and Tapping	+6.2	1.92
Analogies and Cancellation	+5.4	1.91
Completion and Cancellation	+5.4	1.91
Completion and Analogies	0.0	1.79

The + sign indicates that the percentage frequency of occurrence of the final digits 0 and 5 conditioned by the first filling of each pair is greater than that conditioned by the second member of the pair selected.

centage frequency of judgments ending in 0 and 5 than unfilled time as represented by the filling Estimation, (2) intercomparisons of fillings representing filled time point to another interesting relationship. Although no marked difference appears to exist between Cancellation and Tapping as influencing judgments ending in 0 and 5, the fillings Analogies and Completion show reliable differences when compared with Tapping; also Analogies and Completion show reliable differences when compared with Cancellation, (3) remembering that the various fillings indicative of filled time denote various levels of human behavior, from motor behavior to highly mental, we observe a persisting tendency for judgments ending in 0 and 5 to occur more frequently when higher levels of behavior function during the time interval.

The frequencies of the judgments whose final digits are other than 0 and 5 are also influenced by the fillings employed. The last two rows of Table I give the relative frequencies of such judgments. Estimation results in 368 (33.9%) judgments of this type, Tapping 332 (30.5%), Cancellation 323 (29.7%), Analogies 264 (24.3%), and Completion 263 (24.3 %).

2. *Frequency of Occurrence of Correct Judgments*

Table III gives the frequency of occurrence of correct judgments for each of the intervals 15 to 30 seconds. As would be expected, the correct judgments are more numerous for intervals 15, 20, 25, and 30 seconds than for all other intervals employed. The tendency for judgments to end in 0 and 5 will greatly increase the correct judgments of time intervals ending in such digits and lessen the frequency of occurrence of correct judgments of those intervals not ending in 0 and 5.

It is interesting to note the influence of the different fillings upon these correct judgments. This influence has been calculated numerically at the bottom of Table III. Thus it is seen that for Estimation the probability of correct judgments is 0.0450, Tapping 0.0404, Cancellation 0.0395, Analogies 0.0322, and Completion 0.0312. However, when a comparison for these fillings is made in Table IV, which notes the observed differences and their corresponding S. E.'s, we can conclude that there is no reliable difference in frequency of occurrence of correct judgments as conditioned by the various fillings. The S. E.'s are too large as compared with the observed differences. At the bottom of Table III the percentage frequency of correct judgments for all fillings is recorded. This is only 3.77, which indicates the general inaccuracy of judgment of small durations of time.

3. *Effect of Sex upon Estimation of Time*

The median judgments of Groups 1, II, and III for all intervals and fillings are recorded in Table V. Group I comprises 4 male and 8 female graduate students in psychology from Columbia University. Group II consists of 14 male and 14 female students pursuing extension courses at the same University. Group III comprises 28 male undergraduate students from the College of the City of New York. It is clear, then, that Groups I and II are each the combined results for males and females while Group III comprises males only. The amounts of over- and under-estimation, taking the Medians as

TABLE III

FREQUENCY OF OCCURRENCE OF CORRECT JUDGMENTS OF TIME INTERVALS 15-30 SECONDS, 68 JUDGMENTS FOR EACH FILLING

Time (in sec.)	*Estimation*		*Tapping*		*Cancellation*		*Analogies*		*Completion*	
	Frequency	*%*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
15	12	18	7	10.3	11	16.2	12	17.6	11	16.2
16	1	1.5	0	0.	0	0.	2	2.9	0	0.
17	0	0.	1	1.5	0	0.	0	0.	0	0.
18	2	3.	1	1.5	1	1.5	0	0.	0	0.
19	2	3.	2	2.9	0	0.	1	1.5	1	1.5
20	12	17.6	11	16.2	11	16.2	8	11.7	9	13.2
21	0	0.	0	0.	0	0.	1	1.5	0	0.
22	1	1.5	2	2.9	0	0.	0	0.	1	1.5
23	1	1.5	1	1.5	1	1.5	0	0.	0	0.
24	1	1.5	0	0.	0	0.	0	0.	0	0.
25	9	13.2	12	17.6	10	14.7	3	4.4	2	2.9
26	0	0.	1	1.5	1	1.5	0	0.	0	0.
27	0	0.	1	1.5	0	0.	0	0.	1	1.5
28	1	1.5	3	4.4	0	0.	0	0.	0	0.
29	0	0.	0	0.	0	0.	0	0.	0	0.
30	7	10.3	2	2.9	8	11.7	8	11.7	9	13.2
Total frequency	49		44		43		35		34	
Total percentage frequency (N = 1088)		4.50		4.04		3.95		3.22		3.12

Frequency of Occurrence of Correct Judgments for all Fillings = 205 (3.77%)

TABLE IV

DIFFERENCES AND THEIR S. E.'S BETWEEN THE FREQUENCIES OF CORRECT JUDGMENTS OF TIME INTERVALS 15 TO 30 SECONDS WHEN A COMPARISON OF FILLINGS IS MADE. COMBINED RESULTS FOR MALES AND FEMALES
N = 1088

Compared Fillings	*Difference*	*S. E. diff.*
Estimation and Tapping	+0.46%	0.86%
Estimation and Cancellation	+0.55	0.86
Estimation and Analogies	+1.28	0.82
Estimation and Completion	+1.38	0.82
Tapping and Cancellation	+0.09	0.84
Tapping and Analogies	+0.82	0.80
Tapping and Completion	+0.92	0.80
Cancellation and Analogies	+0.73	0.80
Cancellation and Completion	+0.83	0.79
Analogies and Completion	+0.10	0.75

The + sign denotes that the percentage frequency of occurrence of correct judgments conditioned by the first filling of each pair is greater than that conditioned by the second member of the pair.

the central tendencies of the judgments, appear in Table VI. A glance at Table VI is sufficient to show the effect of different groups upon time-estimation. The most striking fact here is the pronounced tendency to underestimate time by Group III when the fillings are conditioned by Estimation and Tapping. The results for Groups I and II, on the contrary, show overestimations in every instance. A comparison of the results of the groups with respect to the other fillings reveals a similar relationship. As a result of the fillings Cancellation, Analogies, and Completion, nearly all the judgments are underestimations, but obviously this tendency is much more pronounced in Group III. An explanation of the preponderance of underestimation of the judgments by Group III over Groups I and II is now in order.

It is impossible to obtain except by chance exactly the same results when similar groups of individuals are measured with respect to any trait. The limited number of measurements causes a certain amount of unreliability of the results obtained, known as "errors of simple sampling." But a careful study of Table VI indicates that there is some influence at work in Group III quite different from that of the other groups. As has been stated, Groups I and II comprise males and females, Group III males only. An analysis of Groups I and II shows distinct sex differences in judgment of small durations of time. A distribution of these judgments for each

TABLE V

Medians of Judgments of Time Intervals (15-30 Seconds) of Individual Groups I, II, and III

Objective Time in Seconds	*Estimation*			*Tapping*			*Cancellation*			*Analogies*			*Completion*		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
15	30.0	20.0	13.5	22.5	20.0	22.0	13.0	13.0	10.0	13.5	15.0	10.0	12.5	10.0	10.0
16	21.5	20.5	15.0	22.0	24.5	15.0	19.5	14.5	10.0	12.5	15.0	10.0	20.0	10.0	10.0
17	27.5	21.5	15.0	24.0	30.0	15.0	16.5	15.0	10.0	15.0	15.0	10.0	20.0	12.0	10.0
18	22.5	22.5	14.5	22.5	26.5	20.0	18.5	15.0	15.0	17.5	15.0	10.0	20.0	12.0	10.0
19	22.0	22.0	15.0	31.5	25.0	20.0	22.0	19.0	15.0	20.0	17.0	10.0	13.5	15.0	10.0
20	22.5	25.0	17.5	29.5	23.5	20.0	19.0	20.0	14.5	16.0	17.5	10.0	14.5	15.0	15.0
21	21.5	25.0	20.0	22.5	25.0	20.0	20.0	22.5	15.0	20.0	20.0	11.0	15.0	15.0	10.0
22	48.5	27.0	15.0	27.5	30.0	20.0	15.0	20.0	11.0	20.0	20.5	10.0	16.0	15.0	12.0
23	37.5	28.5	18.5	27.5	30.5	20.0	24.0	20.0	14.5	20.0	20.0	10.0	25.0	20.0	10.0
24	30.5	29.0	20.0	25.0	37.0	20.0	23.0	20.0	15.0	17.5	15.0	10.0	20.0	16.5	10.0
25	26.5	30.0	21.0	27.5	30.0	25.0	18.5	20.0	15.0	20.0	15.5	11.0	15.0	15.0	10.0
26	31.5	30.0	22.5	30.0	42.5	25.0	28.0	20.0	15.0	20.0	19.5	15.0	27.0	15.0	10.0
27	30.0	30.0	20.0	40.0	32.5	25.0	26.5	25.0	15.0	22.5	20.0	12.5	20.0	20.0	10.0
28	30.0	35.0	22.5	32.5	29.0	20.5	25.0	25.0	10.0	25.0	20.0	10.0	20.0	20.0	10.0
29	30.0	30.0	25.0	30.0	30.0	23.5	22.5	28.5	15.0	27.5	25.0	15.0	14.5	20.0	10.0
30	32.5	32.5	25.0	36.0	35.0	25.0	27.5	25.0	15.0	25.0	14.5	15.0	20.0	20.0	12.5

TABLE VI

AMOUNT OF OVER- AND UNDER-ESTIMATION OF INTERVALS FOR GROUPS I, II, AND III

Objective Time in Seconds	*Estimation*			*Tapping*			*Cancellation*			*Analogies*			*Completion*		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
15	+15.0	+5.0	—1.5	+ 7.5	+ 5.0	+1.0	—2.0	—2.0	— 5.0	—1.5	0.0	— 5.0	— 2.5	— 5.0	— 5.0
16	+ 5.5	+4.5	—1.0	+ 6.0	+ 8.5	—1.0	+3.5	—1.5	— 6.0	—3.5	— 1.0	— 6.0	+ 4.0	— 6.0	— 6.0
17	+10.5	+4.5	—2.0	+ 7.0	+13.0	—2.0	—0.5	—2.0	— 7.0	—2.0	— 2.0	— 7.0	+ 3.0	— 5.0	— 7.0
18	+ 4.5	+4.5	—3.5	+ 4.5	+ 8.5	+2.0	+0.5	—3.0	— 3.0	—0.5	— 3.0	— 8.0	+ 2.0	— 6.0	— 8.0
19	+ 3.0	+3.0	—4.0	+12.5	+ 6.0	+1.0	+3.0	0.0	— 4.0	+1.0	— 2.0	— 9.0	— 5.5	— 4.0	— 9.0
20	+ 2.5	+5.0	—2.5	+ 9.5	+ 3.5	0.0	—1.0	0.0	— 5.5	—4.0	— 2.5	—10.0	— 5.5	— 5.0	— 5.0
21	+ 0.5	+4.0	—1.0	+ 1.5	+ 4.0	—1.0	—1.0	+1.5	— 6.0	—1.0	— 1.0	—10.0	— 6.0	— 6.0	—11.0
22	+26.5	+5.0	—7.0	+ 5.5	+ 8.0	—2.0	—7.0	—2.0	—11.0	—2.0	— 1.5	—12.0	— 6.0	— 7.0	—10.0
23	+14.5	+5.5	—4.5	+ 4.5	+ 7.5	—3.0	+1.0	—3.0	— 8.5	—3.0	— 3.0	—13.0	+ 2.0	— 3.0	—13.0
24	+ 6.5	+5.0	—4.0	+ 1.0	+13.0	—4.0	—1.0	—4.0	— 9.0	—6.5	— 9.0	—14.0	— 4.0	— 7.5	—14.0
25	+ 1.5	+5.0	—4.0	+ 2.5	+ 5.0	0.0	—6.5	—5.0	—10.0	—5.0	— 9.5	—14.0	—10.0	—10.0	—15.0
26	+ 5.5	+4.0	—3.5	+ 4.0	+16.5	—1.0	+2.0	—6.0	—11.0	—6.0	— 6.5	—11.0	+ 1.0	—11.0	—16.0
27	+ 3.0	+3.0	—7.0	+13.0	+ 5.5	—2.0	—0.5	—2.0	—12.0	—4.5	— 7.0	—14.5	— 7.0	— 7.0	—17.0
28	+ 2.0	+7.0	—5.5	+ 4.5	+ 1.0	—7.5	—3.0	—3.0	—18.0	—3.0	— 8.0	—18.0	— 8.0	— 8.0	—18.0
29	+ 1.0	+1.0	—4.0	+ 1.0	+ 1.0	—5.5	—6.5	—0.5	—14.0	—1.5	— 4.0	—14.0	—14.5	— 9.0	—19.0
30	+ 2.5	+2.5	—5.0	+ 6.0	+ 5.0	—5.0	—2.5	—5.0	—15.0	—5.0	—15.5	—15.0	—10.0	—10.0	—17.5

The + denotes over-estimation; the — under-estimation.

sex is contained in Tables VIIa and VIIb. Two sample intervals, 20″ and 30″, were selected as characteristic of the 16 intervals chosen for the experiment. The Medians, Median Deviations, and Probable Errors of the Medians (P.E.$_{\text{t - obt med}}$) are recorded in Table VIII.

TABLE VIIa

DISTRIBUTION OF MALE AND FEMALE JUDGMENTS IN 10″ CLASSES TIME INTERVAL = 20 SECONDS (18 MALES AND 22 FEMALES).

Classes	*Estimation*		*Tapping*		*Cancellation*		*Analogies*		*Completion*	
	M	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
0- 9	1	0	0	0	3	0	3	2	4	0
10- 19	9	0	9	3	7	8	11	11	11	12
20- 29	4	13	4	8	3	7	2	6	3	8
30- 39	2	4	2	5	3	6	1	2		1
40- 49	0	3	2	2	2	0	1	1		0
50- 59	1	1	1	1		1				0
60- 69	1	0		1						1
70- 79		0		1						
80- 89		1		0						
90- 99				0						
100-109				1						

TABLE VIIb

DISTRIBUTION OF MALE AND FEMALE JUDGMENTS IN 10″ CLASSES TIME INTERVAL = 30 SECONDS (18 MALES AND 22 FEMALES)

Classes	*Estimation*		*Tapping*		*Cancellation*		*Analogies*		*Completion*	
	M	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
0- 9	0	0	0	0	0	0	2	0	0	0
10- 19	1	0	1	3	6	3	7	9	9	10
20- 29	10	2	9	3	6	7	5	5	6	9
30- 39	2	10	2	5	3	5	3	4	2	2
40- 49	1	4	2	5	2	3	1	3	1	1
50- 59	2	2	1	1	0	2		0		
60- 69	2	3	2	1	1	2		1		
70- 79		0	1	1						
80- 89		0		0						
90- 99		0		0						
100-109		0		0						
110-119		0		1						
120-129		1		1						
130-139				0						
140-149				0						
150-159				1						

A survey of Table VIII shows at once that the central tendency for females is much higher than that for males. This is true whatever filling is employed. Table IX gives the differences between the Medians of the judgments of the sexes.

Each obtained difference is accompanied by its Probable Error ($\text{P.E.}_{\text{diff}}$) which has been determined by the aid of the following formula:

$$\text{P.E.}_{(\text{t.—obt. Diff. A—B})} = \sqrt{(Q_{\text{t.—obt. A}})^2 + (Q_{\text{t.—obt. B}})^2}$$

For the P.E. of the Median, the following formula was employed:

$$\text{P.E.}_{\text{t. med.—obt. med.}} = \frac{5}{4}\,\frac{Q\text{ dis.}}{\sqrt{n}}$$

Here the Median Deviation (Med. Dev.) has been substituted for Q (semi-quartile range) since the two would always be practically identical. The similarity between the Med. Dev. and Q was made certain by a comparison of the two, selecting ten random samples of each from the given data.

Table IX shows that the sex differences in estimation of time are reliable. The majority of the obtained differences are more than three times their Probable Errors and no obtained difference is less than twice its P.E. These sex differences now clarify the apparently inconsistent results for Groups I, II, and III. The comparatively low estimates for the males are counteracted by the exceedingly high estimates for the females, and the results show higher estimations by Groups I and II than is the case with Group III.

Observing the results for Group III in Table VI and the Medians for males recorded in Table VIII, we are forced to the conclusion that there is a strong tendency for males to underestimate durations of time ranging from 15 to 30 sec-

TABLE VIII

MEDIANS, ETC., FOR EACH SEX, FILLING, AND SAMPLE INTERVALS (20″ AND 30″)

		Medians		*Med. Dev.*		*P. E. t-obt. med.*	
		Males	*Females*	*Males*	*Females*	*Males*	*Females*
	Estimation	18.5	25.5	6.5	5.5	1.91	1.46
	Tapping	18.5	29.0	3.5	9.0	1.02	2.39
20″	Cancellation	14.0	24.5	7.5	6.5	2.20	1.72
	Analogies	12.5	18.0	3.5	7.5	1.02	1.99
	Completion	13.0	18.0	3.5	7.0	1.02	1.86
	Estimation	27.0	36.5	6.0	6.5	1.76	1.72
	Tapping	26.0	38.0	6.0	10.5	1.76	2.79
30″	Cancellation	20.0	32.0	7.5	8.0	2.20	2.12
	Analogies	18.0	25.5	5.5	7.5	1.61	1.99
	Completion	14.0	24.0	7.0	7.5	2.05	1.99

onds. This is true for every filling. Only in 3 instances (Table VI, Group III, Tapping) are there overestimations by the males, and these are very slight. In the case of the females, however, marked overestimations appear for Estimation and Tapping (Table VIII). For the filling Cancellation there is also a slight tendency toward overestimation. In the case of the 30″ interval the reliability of this overestimation as indicated by the P.E. of the Median is very low. When the 20″ interval is considered, the overestimation caused by Cancellation is fairly reliable. The tendency for Analogies and Completion is to produce underestimations but the reliability of this underestimation holds only for the 30″ interval.

TABLE IX

DIFFERENCES AND PROBABLE ERRORS OF THE DIFFERENCES BETWEEN MEDIANS OF JUDGMENTS OF MALES AND FEMALES. THE PLUS SIGN DENOTES THAT THE MEDIAN FOR FEMALES IS GREATER THAN THAT FOR MALES

Objective Time in Seconds	*Estimation*		*Tapping*		*Cancellation*		*Analogies*		*Completion*	
	Diff.	*P.E. diff.*	*Diff.*	*P.E. diff.*	*Diff.*	*P.E. diff.*	*Diff.*	*P.E. diff.*	*Diff.*	*P.E. diff.*
20	+7.0	2.40	+10.5	2.59	+10.5	2.79	+5.5	2.23	+ 5.0	2.12
30	+9.5	2.45	+12.0	3.30	+12.0	3.05	+7.5	2.55	+10.0	2.85

In general, these results pertaining to differences in judgment of time due to sex are in accord with the results obtained by Robert MacDougall[3] and Yerkes and Urban[4]. The former found that "the tendency toward over-estimation is very much stronger in the women than in the men. In the case of the men, keeping tally of the passing seconds results in the elimination of the positive error and the appearance of a slight under-estimation." Yerkes and Urban also found that when the subjects are permitted to employ whatever method of estimating time they find most serviceable for the purpose (except the use of a timepiece), the tendency for men is to underestimate and for women to overestimate small durations of time (36″ to 108″).

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[3] MacDougall, Robert. Op. cit.

[4] Yerkes and Urban. Op. cit.

4. *Effect of Various Fillings upon Estimation of Time*

The combined results for Groups I, II, and III are presented in Tables X to XIV, which give the distributions of the judgments for each interval and filling. Since it was found that the judgments are influenced by the final digits 0 and 5, it proved advisable to group these judgments in 10″ classes. Each class would then be influenced equally by this tendency. Tables X to XIV impress us at once with the fact that individuals vary greatly in their judgments of time. When the filling Estimation is introduced (Table X), the judgment of an objective interval of 15 seconds is as low as 5 seconds and

TABLE X

Distribution of Judgments in 10″ Classes for Estimation.

Classes	*Objective Time in Seconds*															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0- 9	3	3	5	2	3	5	0	1	0	1	1	0	2	1	0	0
10- 19	35	32	28	31	30	15	18	22	18	14	15	15	12	13	13	6
20- 29	13	18	18	18	25	30	23	18	23	28	20	27	20	20	13	18
30- 39	8	10	9	9	3	13	12	9	13	12	19	11	24	15	25	17
40- 49	3	3	4	6	5	3	12	5	4	4	7	5	2	11	6	17
50- 59	3	0	1	1	2	1	1	3	3	4	3	2	1	3	5	4
60- 69	2	2	2	0		0	1	3	4	3	1	4	6	4	5	5
70- 79	0		0	1		0	0	5	0	0	1	2	0	0	0	0
80- 89	0		1			1	0	0	0	0	0	1	0	0	0	0
90- 99	1						1	2	1	1	0	0	0	0	0	0
100-109									2	1	1	1	0	0	1	0
110-119													0	0		0
120-129													1	1		1

TABLE XI

Distribution of Judgments in 10″ Classes for Tapping.

Classes	*Objective Time in Seconds*															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0- 9	5	3	3	3	1	1	2	2	1	1	0	3	0	0	0	0
10- 19	29	31	29	18	28	21	18	17	20	13	11	8	9	12	7	9
20- 29	23	22	17	26	21	26	29	23	22	30	27	21	25	21	26	21
30- 39	8	8	10	13	8	10	10	15	8	6	19	18	16	19	20	9
40- 49	2	2	5	5	5	5	4	5	10	9	5	11	10	8	5	17
50- 59	0	1	2	1	2	2	2	3	3	4	1	0	3	1	4	4
60- 69	1	1	2	1	0	1	0	3	1	5	3	2	2	3	2	3
70- 79				0	1	1	0		2		0	2	0	1	0	2
80- 89				1	1	0	0		0		0	0	0	0	1	0
90- 99					0	0	3		1		1	1	1	0	0	0
100-109					1	1					0	1	0	2	1	0
110-119											1	0	1	0	1	1
120-129												1	0	0	0	1
130-139													0	0	0	0
140-149													1	0	0	0
150-159														1	1	1

TABLE XII

Distribution of Judgments in 10″ Classes, for Cancellation Test.

Classes	Objective Time in Seconds															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0- 9	16	20	20	14	9	13	8	13	9	6	8	12	6	8	8	5
10-19	38	28	28	28	27	25	28	30	25	29	26	26	24	20	17	23
20-29	9	10	11	15	23	16	19	13	19	19	24	16	20	21	21	18
30-39	1	6	6	6	6	10	9	5	5	8	4	7	7	10	11	10
40-49	2	4	3	3	3	3	4	4	4	1	2	3	6	6	6	7
50-59	1			2		1		0	1	1	3	3	5	2	2	2
60-69	1							2	4	4	1	0		1	3	3
70-79								1	1			0				
80-89												0				
90-99												1				

TABLE XIII

Distribution of Judgments in 10″ Classes, for Analogies.

Classes	Objective Time in Seconds															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0- 9	20	16	18	19	16	17	9	15	7	10	7	8	9	11	7	8
10- 19	30	37	30	33	28	36	35	28	36	34	35	33	23	26	29	26
20- 29	12	8	14	7	19	12	16	10	12	12	17	16	28	21	15	22
30- 39	3	6	5	8	3	2	6	7	7	8	6	9	4	6	8	8
40- 49	1	1	1	0	2	1	2	7	3	2	2	1	3	1	7	3
50- 59	0			1				0	1	1	1	1	1	2	2	0
60- 69	1							1	1	1				1		1
70- 79	0								0							
80- 89	0								0							
90- 99	1								0							
100-109									1							

TABLE XIV

Distribution of Judgments in 10″ Classes, Completion Test.

Classes	Objective Time in Seconds															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0- 9	25	27	24	23	14	13	13	16	14	15	14	16	12	15	11	9
10-19	28	25	25	28	40	34	36	29	30	29	36	31	31	25	32	28
20-29	8	10	10	9	7	13	15	11	13	15	16	10	18	18	13	18
30-39	3	6	8	6	6	5	3	9	7	7	2	7	4	8	9	10
40-49	4		1	1	1	0	1	1	4	2		3	1	0	3	2
50-59				1		0		1				0	1	2		0
60-69						3		1				1	0			1
70-79													0			
80-89													0			
90-99													1			

as high as 90 seconds. The judgment of a 27-second interval ranges from 5 seconds to 120 seconds. Table XI also shows great variability of response but in Tables XII, XIII, and XIV

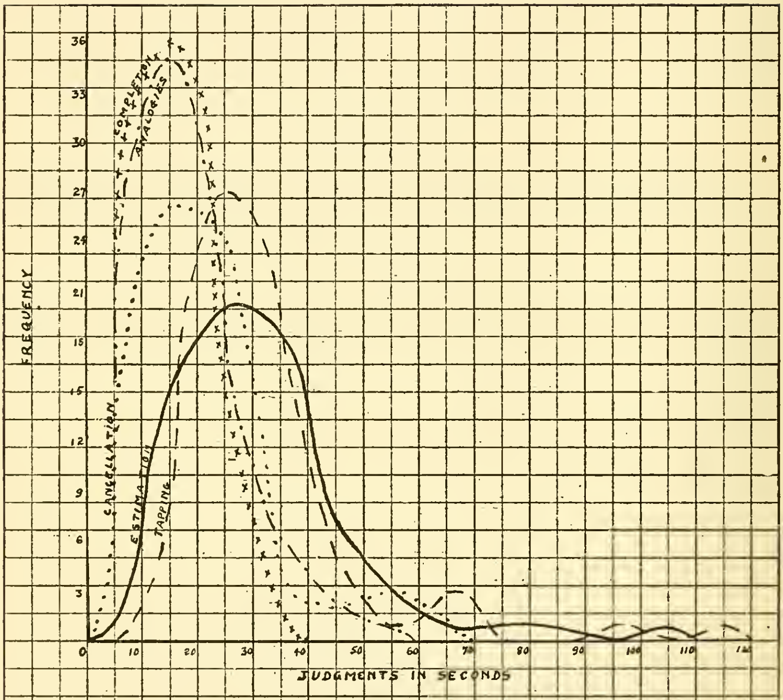

FIG. I. — DISTRIBUTION OF JUDGMENTS FOR ALL FILLINGS. SAMPLE TIME-INTERVAL — 25"

we observe a greater persistency for similarity of judgment. This closer agreement of judgment in the case of Cancellation, Analogies, and Completion becomes, however, less significant when we take into consideration the difference in the central tendencies (recorded in Table XV). The central tendencies when, for example, Tapping is employed as a filling are larger than for Completion and hence a larger range of the judgments in the former would be expected. Figure 1 is an instance of the asymmetry of distribution which exists in the judgment of time. Its most characteristic attribute is skewness. The positive skewness of the general curve of judgment of short durations of time can be easily explained. The subject is asked to judge an interval of, let us say, 20 seconds. However his tendency to underestimate time may be, he cannot judge this interval to be less than zero seconds. If he should judge 20 seconds to be zero seconds, he has underestimated this objective interval by 20 seconds. Now consider the individual with a tendency to overestimate time. His judgment is not limited by zero time but by infinity. However large the central tendency may be, the lower half of the curve of distribution is bounded by zero while the upper portion has no restricted limit. Since there exist individual differences in the judgment of time, the amount of positive skewness will depend upon the group tested.

We are now confronted with the following problem: What is the effect of the various fillings upon the central tendencies and variabilities of the judgments of time intervals ranging from 15 to 30 seconds? Obviously, if the fillings are selected at random and differences in judgment of time are discovered, the only possible conclusion would be that judgment of time depends upon how the time interval is filled. That this is the case has already been satisfactorily demonstrated by previous investigators of the time-sense. As has been mentioned in our problem, a classification of fillings in terms of complexity of human behavior will give us a clearer conception of the fundamental principle operating in our judgment of the duration of time. The writer does not insist that an absolute classification is possible. We classify phenomena for the purpose of simplification and to gain a clearer conception of fundamental laws. Without classification our conceptions would be chaotic. Here, the fillings have been classified according to the level of behavior which functions during a given length of time.

Psychologists such as Bagley[5], Bolton[6], Hollingworth[7], and Whipple[8] have generally agreed that simple motor work is quite different from mental work. Whipple regards the filling Cancellation, which we have designated as sensori-motor work, as a type of activity which lies somewhere between simple motor work and mental work. An attempt has been made here to select fillings which will fall into each of these classes. Tapping has been selected as representative of motor activity. Of course, it is as yet impossible to determine whether Tapping is a purely motor function or a low form of mental activity. But if it is kept in mind that the terms "motor" and "mental" do not imply absolute classification and that some overlapping of the two is unavoidable, the fillings selected to represent the different classes of human behavior will be found adequate.

Another filling selected by the author deserves especial mention. The expression "unfilled time" has been used by philosophers and psychologists alike as if such a condition really exists. Since the individual is constantly stimulated by external and internal stimuli a state of "empty time" or "unfilled time" is impossible so far as the human organism is concerned. Unfilled time, therefore, is a term used to denote a certain state of activity. This condition can be brought about by such stimuli as the oral or written command "Attention!", a sudden shock, stimulations resulting in sleep, the command to keep quiet, etc. Here the term Estimation represents a type of "unfilled time." With this understanding of the nature of the fillings selected for experimentation, let us see how judgment of time is influenced thereby.

Table XV records the Averages and Medians of time intervals, 15 to 30 seconds for the combined groups. Table XVI gives the Median Deviations from the Medians and the P. E.'s of the Medians. The amounts of over- and under-estimation are clearly presented in Table XVII. Here it will be observed that for Estimation and Tapping all of the time intervals ranging from 15 to 30 seconds are overestimated. Not a single

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[5] Bagley, W. C. "On the Correlation of Mental and Motor Ability in School Children," Amer. J. of Psychol., 1901, 12, pp. 193-205.

[6] Bolton, T. L. "The Relation of Motor Power to Intelligence," Amer. J. of Psychol., 1903, 14, pp. 615-631.

[7] Hollingworth, H. L. "The Influence of Caffein on Mental and Motor Efficiency," Archives of Psychol., 1912, 22.

[8] Whipple, G. M. "Manual of Mental and Physical Tests, Part 1," Warwick & York, Inc., Baltimore, Md., 1914, pp. 130-147.

TABLE XV

AVERAGES AND MEDIANS OF JUDGMENTS OF TIME INTERVALS (15-30 SEC.) COMBINED RESULTS FOR GROUPS I, II AND III.

Objective Time in Seconds	*Estimation*		*Tapping*		*Cancellation*		*Analogies*		*Completion*	
	Av.	*Med.*	*Av.*	*Med.*	*Av.*	*Med.*	*Av.*	*Med.*	*Av.*	*Med.*
15	21.8	16.0	19.2	19.0	14.2	11.5	14.8	11.0	13.3	10.0
16	20.3	19.0	20.1	19.0	15.3	13.0	13.6	12.0	12.4	10.0
17	21.9	20.0	22.4	20.0	15.2	13.0	14.1	11.0	13.5	10.0
18	21.0	20.0	24.7	24.0	17.1	15.0	14.4	12.0	13.6	10.0
19	20.5	20.0	25.0	20.0	18.1	18.0	15.7	15.0	14.4	12.0
20	22.2	22.5	26.0	21.0	18.2	15.0	14.0	15.0	16.3	14.5
21	23.2	23.5	25.6	23.5	19.3	18.0	16.6	15.0	14.6	15.0
22	30.5	24.0	26.7	22.5	18.6	15.0	17.6	15.0	16.0	15.0
23	28.8	25.0	28.7	24.0	21.8	19.0	19.2	15.0	16.1	14.5
24	27.0	25.0	28.3	25.0	20.6	18.0	16.9	15.0	15.8	15.0
25	27.2	26.5	28.7	27.5	20.0	19.0	16.8	15.0	13.8	13.5
26	29.7	27.0	34.4	30.0	20.3	16.0	18.0	15.0	15.8	11.0
27	29.0	27.5	32.2	29.0	23.1	20.0	18.6	20.0	16.9	15.0
28	30.8	29.5	33.0	30.0	22.6	20.0	18.5	15.0	16.6	15.0
29	31.0	31.0	33.9	30.0	23.4	20.0	21.4	17.0	17.3	15.0
30	32.6	32.5	35.6	33.5	23.9	20.0	19.4	19.5	17.4	15.5

TABLE XVI

MEDIAN DEVIATIONS FROM THE MEDIANS AND PROBABLE ERRORS OF THE MEDIANS OF JUDGMENTS OF TIME INTERVALS (15-30 SECONDS).

COMPOSITE OF GROUPS I, II AND III.

Objective Time in Seconds	*Estimation*		*Tapping*		*Cancellation*		*Analogies*		*Completion*	
	Med. Dev.	*P.E.*	*Med. Dev.*	*P.E.*	*Med. Dev.*	*P.E.*	*Med. Dev.*	*P.E.*	*Med. Dev.*	*P.E.*
15	6.0	0.91	7.0	1.06	3.5	0.53	5.0	0.76	5.0	0.76
16	6.0	0.91	6.0	0.91	6.0	0.91	3.0	0.45	5.0	0.76
17	7.5	1.14	7.0	1.06	6.0	0.91	4.0	0.60	5.0	0.76
18	7.0	1.06	6.0	0.91	5.0	0.76	3.5	0.53	5.0	0.76
19	5.0	0.76	5.0	0.76	6.0	0.91	5.0	0.76	3.0	0.45
20	7.5	1.14	6.0	0.91	5.0	0.76	5.0	0.76	5.0	0.76
21	6.5	0.98	6.5	0.98	8.0	1.21	5.0	0.76	5.0	0.76
22	9.0	1.36	7.5	1.14	5.0	0.76	5.5	0.83	5.0	0.76
23	6.5	0.98	7.0	1.06	7.0	1.06	5.0	0.76	5.5	0.83
24	5.5	0.83	6.0	0.91	7.0	1.06	5.0	0.76	5.0	0.76
25	5.5	0.83	4.5	0.68	6.0	0.91	5.0	0.76	3.5	0.53
26	7.0	1.06	9.0	1.36	6.0	0.91	5.0	0.76	4.0	0.60
27	7.5	1.14	7.5	1.14	8.0	1.21	5.0	0.76	5.0	0.76
28	9.5	1.44	9.5	1.44	10.0	1.52	5.0	0.76	5.0	0.76
29	9.0	1.36	9.0	1.36	10.0	1.52	7.0	1.06	5.0	0.76
30	7.5	1.14	11.5	1.74	8.5	1.29	5.5	0.83	5.5	0.83

TABLE XVII

AMOUNT OF OVER- AND UNDER-ESTIMATION OF JUDGMENTS.
COMBINED RESULTS FOR GROUPS I, II AND III.

Objective Time (T) in Seconds	*Estimation*		*Tapping*		*Cancellation*		*Analogies*		*Completion*	
	T-Av.	*T-Med.*	*T-Av.*	*T-Med.*	*T-Av.*	*T-Med.*	*T-Av.*	*T-Med.*	*T-Av.*	*T-Med.*
15	+6.8	+1.0	+4.2	+4.0	—0.8	—3.5	—0.2	—4.0	—1.7	—5.0
16	+4.3	+3.0	+4.1	+3.0	—0.7	—3.0	—2.4	—4.0	—3.6	—6.0
17	+4.9	+3.0	+5.4	+3.0	—1.8	—4.0	—2.9	—6.0	—3.5	—7.0
18	+3.0	+2.0	+6.7	+6.0	—0.9	—3.0	—3.6	—6.0	—4.4	—8.0
19	+1.5	+1.0	+6.0	+1.0	—0.9	—1.0	—3.3	—4.0	—4.6	—7.0
20	+2.2	+2.5	+6.0	+1.0	—1.8	—5.0	—6.0	—5.0	—3.7	—5.5
21	+2.2	+2.5	+4.6	+2.5	—1.7	—3.0	—4.4	—6.0	—6.4	—6.0
22	+8.5	+2.0	+4.7	+0.5	—3.4	—7.0	—4.4	—7.0	—6.0	—7.0
23	+5.8	+2.0	+5.7	+1.0	—1.2	—4.0	—3.8	—8.0	—6.9	—8.5
24	+3.0	+1.0	+4.3	+1.0	—3.4	—6.0	—7.1	—9.0	—8.2	—9.0
25	+2.2	+1.5	+3.7	+2.5	—5.0	—6.0	—8.2	—10.0	—11.2	—11.5
26	+3.7	+1.0	+8.4	+4.0	—5.7	—10.0	—8.0	—11.0	—10.2	—15.0
27	+2.0	+0.5	+5.2	+2.0	—3.9	—7.0	—8.4	—7.0	—10.1	—12.0
28	+2.8	+1.5	+5.0	+2.0	—5.4	—8.0	—9.5	—13.0	—11.4	—13.0
29	+2.0	+2.0	+4.9	+1.0	—5.6	—9.0	—7.6	—12.0	—11.7	—14.0
30	+2.6	+2.5	+5.6	+3.5	—6.1	—10.0	—10.6	—10.5	—12.6	—14.5

T-Av. represents the difference in seconds between the objective time and the mean of the judgments.

T-Med. denotes the difference in seconds between the objective time and the Median of the judgments.

The + sign indicates overestimation; the — sign indicates underestimation.

instance of underestimation is to be found. When we examine the results for Cancellation, Analogies, and Completion the contrary is in evidence. All of the average or median judgments are underestimations. The effect of the filling upon the character of judgment does not depend upon the measure of central tendency we employ. Whether the Average or Median is used as a central tendency the significance of over- or underestimation remains unaltered.

Thus far we have grouped the effects of the fillings into two classes, i.e., those which produce overestimations and those which produce underestimations. Let us now attempt a classification of fillings which depends upon magnitude of judgment. The object of this procedure will be to arrange these fillings in order of magnitude of the judgments which they provoke.

Table XVIII gives the differences between the Medians of the judgments of each time interval when a comparison of the influence of the different fillings is made. The first row records the successive time intervals from 15 to 30 seconds. Each succeeding row lists the differences between the Medians for each interval when the judgments with respect to two different fillings are compared. For example, -3.0 shows that when the 15″ interval is selected, the Median of the judgments for Tapping is 3 seconds larger than the Median of the judgments for Estimation. The difference 0.0″ indicates that the Medians for the two fillings are identical. The difference +1.5″ means that the central tendency of the judgments is larger for Estimation than for Tapping. Thus 16 comparisons are made for each pair of fillings, or 160 comparisons in all.

A detailed analysis of Table XVIII is necessary for a clear understanding of the influence of the different fillings upon estimation of time. A close examination of Estimation and Tapping as conditioning judgment of time gives us the following facts: (1) Of the 16 time intervals selected, 4 intervals give median judgments which are larger for Estimation than for Tapping (+1.5″, +1.5″, +1.0″, +1.0″); (2) 7 intervals give median judgments which are larger for Tapping than for Estimation (–3.0″, –4.0″, –1.0″, –3.0″, –1.5″, –0.5″, –1.0″); (3) 5 intervals indicate identical Medians (5 occurrences of 0.0″). The Median of these differences is 0.0″, which indicates that there is no difference between Estimation and Tapping as factors influencing judgment of these time intervals.

TABLE XVIII

DIFFERENCES BETWEEN MEDIANS OF DISTRIBUTIONS OF JUDGMENTS OF TIME INTERVALS (15-30 SECONDS) WHEN A COMPARISON OF FILLINGS IS MADE

Objective Time in Seconds	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Estimation & Tapping	—3.0	0.0	0.0	— 4.0	0.0	+1.5	0.0	+1.5	+ 1.0	0.0	— 1.0	— 3.0	— 1.5	— 0.5	+ 1.0	— 1.0
Estimation & Cancellation	+4.5	+6.0	+ 7.0	+ 5.0	+2.0	+7.5	+5.5	+9.0	+ 6.0	+ 7.0	+ 7.5	+11.0	+ 7.5	+ 9.5	+11.0	+12.5
Estimation & Analogies	+5.0	+7.0	+ 9.0	+ 8.0	+5.0	+7.5	+8.5	+9.0	+10.0	+10.0	+11.5	+12.0	+ 7.5	+14.5	+14.0	+13.0
Estimation & Completion	+6.0	+9.0	+10.0	+10.0	+8.0	+8.0	+8.5	+9.0	+10.5	+10.0	+13.0	+16.0	+12.5	+14.5	+16.0	+17.0
Tapping & Cancellation	+7.5	+6.0	+ 7.0	+ 9.0	+2.0	+6.0	+5.5	+7.5	+ 5.0	+ 7.0	+ 8.5	+14.0	+ 9.0	+10.0	+10.0	+13.5
Tapping & Analogies	+8.0	+7.0	+ 9.0	+12.0	+5.0	+6.0	+8.5	+7.5	+ 9.0	+10.0	+12.5	+15.0	+ 9.0	+15.0	+13.0	+14.0
Tapping & Completion	+9.0	+9.0	+10.0	+14.0	+8.0	+6.5	+8.5	+7.5	+ 9.5	+10.0	+14.0	+19.0	+14.0	+15.0	+15.0	+18.0
Cancellation & Analogies	+0.5	+1.0	+ 2.0	+ 3.0	+3.0	0.0	+3.0	0.0	+ 4.0	+ 3.0	+ 4.0	+ 1.0	0.0	+ 5.0	+ 3.0	+ 0.5
Cancellation & Completion	+1.5	+3.0	+ 3.0	+ 5.0	+6.0	+0.5	+3.0	0.0	+ 4.5	+ 3.0	+ 5.5	+ 5.0	+ 5.0	+ 5.0	+ 5.0	+ 4.5
Analogies & Completion	+1.0	+2.0	+ 1.0	+ 2.0	+3.0	+0.5	0.0	0.0	+ 0.5	0.0	+ 1.5	+ 4.0	+ 5.0	0.0	+ 2.0	+ 4.0

The symbol + indicates that the Median of the judgments conditioned by the first filling of each pair is greater than the Median of the judgments of the time interval corresponding to the second member (filling) of the pair selected. The symbol — denotes the reverse.

TABLE XIX

PROBABLE ERRORS OF THE DIFFERENCES BETWEEN THE MEDIANS OF DISTRIBUTIONS OF JUDGMENTS OF TIME INTERVALS (15-30 SECONDS) WHEN A COMPARISON OF THE INFLUENCE OF FILLINGS IS MADE

Objective Time in Seconds	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Estimation & Cancellation	1.04	1.28	1.44	1.30	1.16	1.36	1.56	1.56	1.44	1.35	1.23	1.40	1.66	2.09	2.04	1.72
Estimation & Analogies	1.16	1.00	1.28	1.19	1.04	1.37	1.24	1.56	1.24	1.13	1.13	1.30	1.37	1.63	1.73	1.41
Estimation & Completion	1.16	1.16	1.36	1.30	0.84	1.37	1.24	1.52	1.28	1.13	0.99	1.22	1.37	1.63	1.56	1.41
Tapping & Cancellation	1.18	1.28	1.36	1.16	1.16	1.16	1.56	1.36	1.48	1.40	1.14	1.60	1.66	2.09	2.04	2.17
Tapping & Analogies	1.30	1.01	1.20	1.04	1.04	1.16	1.24	1.40	1.28	1.18	1.01	1.52	1.37	1.63	1.73	1.93
Tapping & Completion	1.30	1.18	1.28	1.16	0.84	1.16	1.24	1.36	1.32	1.18	0.86	1.48	1.37	1.63	1.20	1.93
Cancellation & Analogies	0.92	1.00	1.08	0.92	1.16	1.04	1.40	1.12	1.28	1.28	1.16	1.16	1.40	1.68	1.84	1.52
Cancellation & Completion	0.92	1.16	1.16	1.04	1.00	1.04	1.40	1.04	1.32	1.28	1.04	1.08	1.40	1.68	1.68	1.52
Analogies & Completion	1.04	0.84	0.96	0.92	0.84	1.04	1.04	1.12	1.12	1.04	0.92	0.96	1.04	1.04	1.28	1.16

Comparing Estimation and Cancellation, we find that each interval gives positive differences between the respective Medians. In each instance, the median judgment for Estimation is larger than for Cancellation. That these differences are reliable is indicated by the P. E.'s of the differences recorded in Table XIX. Estimation and Analogies, and Estimation and Completion also give positive differences, which means that the median judgments for Estimation are greater than those for Analogies and Completion. When Tapping is compared with Cancellation, Analogies, and Completion, positive differences again appear. From this comparison we can infer that Tapping bears the same relation to Cancellation, Analogies, and Completion in influencing judgment of time as does Estimation.

When Cancellation is compared with Analogies and Completion, we find that only in 4 instances out of 32 differences is the Median for Cancellation equal to that for Analogies and Completion. Twenty-eight differences are positive, and of this number 20 differences are reliable when compared with their corresponding P.E.'s in Table XIX.

Comparing Analogies and Completion, we find that in 12 instances out of 16 the median judgment for Analogies is

TABLE XX

VARIABILITY QUOTIENTS* OF JUDGMENTS OF TIME INTERVALS (15-30 SEC.) COMBINED RESULTS FOR GROUPS I, II AND III.

Objective Time (sec.)	*Estimation*	*Tapping*	*Cancellation*	*Analogies*	*Completion*
15	1.50	1.60	1.03	1.51	1.58
16	1.38	1.38	1.66	0.86	1.58
17	1.67	1.56	1.66	1.20	1.58
18	1.56	1.22	1.29	1.01	1.58
19	1.11	1.11	1.41	1.29	0.86
20	1.58	1.31	1.29	1.29	1.31
21	1.34	1.34	1.88	1.29	1.29
22	1.83	1.58	1.29	1.42	1.29
23	1.30	1.42	1.60	1.29	1.44
24	1.10	1.20	1.65	1.29	1.29
25	1.07	0.85	1.37	1.29	0.95
26	1.34	1.64	1.50	1.29	1.20
27	1.43	1.39	1.78	1.11	1.29
28	1.74	1.73	2.23	1.29	1.29
29	1.61	1.64	2.23	1.69	1.29
30	1.31	1.98	1.90	1.24	1.40

*Median Deviation of the judgments divided by the square root of the Median.

greater than that for Completion, and in no instance is the median judgment for Completion greater than that for Analogies (there are 4 instances of 0.0″). Thus we find a slight tendency for differences in judgment even where different types of mental work are concerned.

Tables XV, XVI, XVII, XVIII and XIX, therefore, point to a definite relationship between judgment of time and the level of behavior which functions during a given interval. The effect of Estimation and Tapping is to cause overestimations of small durations of time for the combined groups. On the other hand, Cancellation, Analogies, and Number Series Completion are types of fillings which produce underestimations. When the influence of the last three types of fillings is analyzed, we find that another line of demarcation can be drawn. Although Cancellation causes underestimation of time, this tendency is much more marked in the case of Analogies and Number Series Completion. Also, the underestimation due to the filling Number Series Completion is slightly greater than that due to Analogies. Thus, the higher the level of human behavior during the time interval the greater is the tendency to underestimate the given interval.

The effect of a given filling upon the variability of judgment of time is shown in Table XX, which records the results derived from Table XVI. The latter gives the variabilities as the Median Deviations of the judgments. In Table XX each of these Median Deviations is divided by the square root of the corresponding central tendency (Median). This Variability Quotient (V) gives a better estimate of the variability for the purpose of comparison. Comparing the Variability Quotients in Table XX for each interval and filling, we find that no relationship exists between the type of filling employed and the magnitude of the variability of the judgments.

5. *Effect of Length of Time Interval upon Amount of Over- or Under-Estimation*

Since 16 successive time intervals have been selected for the purpose of this investigation, it would be interesting to determine whether there exists any definite relationship between the length of the objective time and amount of over- or under-estimation. Since the number of intervals here is limited to 16, the calculated relationship will be significant only within these limits of time. A coefficient of correlation will clearly determine this relationship. From Table XVII we observe that either T-Av. or T-Med. may be employed as a series of measures to be correlated with the objective time. That the choice of either central tendency will not affect our coefficient of correlation to any appreciable extent, can be confirmed by a comparison of the Averages and Medians in Table XV. Although the two measures of central tendency differ somewhat numerically, they have similar tendencies of over- or under-estimation. Using the Median as a measure of the central tendency, the amounts of over- and under-estimation are determined by finding the difference between the objective time and the corresponding median judgment. These differences are recorded in Table XVII. When these differences are correlated with the objective time intervals, we obtain the results shown in Table XXI. The coefficient of correlation here employed is $\rho = 1 - \frac{6\Sigma D^2}{n(n^2-1)}$.

Table XXI gives the effect of increased lengths of time upon the amount of over- or under-estimation by a group. A close examination of Table XXI shows that the influence of increased durations of time upon overestimation when the judgments themselves are overestimations is not significant. Table XXI shows that the P. E.'s in reference to the coefficients –0.23 and –0.22 are too large to attach any significance to these two coefficients. However, when we examine the remaining three coefficients, +0.83, +0.89, and +0.88, and their accompanying P. E.'s we find that they are very significant. We can, therefore, conclude this much from Table XXI: When a given filling causes underestimation of judgment of time, the longer the objective time the larger is the amount of underestimation.

TABLE XXI

RELATION BETWEEN LENGTH OF OBJECTIVE TIME AND AMOUNT OF OVER- OR UNDER-ESTIMATION

Filling	ρ	*P. E.*
Estimation +	—0.23	0.159
Tapping +	—0.22	0.160
Cancellation —	+0.83	0.052
Analogies —	+0.89	0.035
Completion —	+0.88	0.037

+ caused overestimation of judgment of time
— caused underestimation of judgment of time

The question which immediately comes to mind is whether there is any significant relationship between the per cent of over- or under-estimation and the length of the objective interval. This may be determined by dividing the actual amounts of over- or under-estimation by the respective objective times, and correlating these ratios with the objective series of intervals. The obtained results are expressed in Table XXII. Examination of Table XXII shows that for the fillings Estimation and Tapping there is a negative relation between per cent of overestimation and increased durations of time from 15 to 30 seconds to the extent expressed by the coefficients –.54 and –.48. Considering the fillings Cancellation, Analogies, and Completion which cause underestimations, we find that there is a marked tendency for the per cent of underestimation to increase with increased lengths of the objective time.

TABLE XXII

RELATION BETWEEN LENGTH OF OBJECTIVE TIME AND PER CENT OF OVER- OR UNDER-ESTIMATION

Filling	ρ	*P. E.*
Estimation +	—0.54	0.119
Tapping +	—0.48	0.130
Cancellation —	+0.71	0.083
Analogies —	+0.61	0.105
Completion —	+0.66	0.095

+ caused overestimation of judgment of time
— caused underestimation of judgment of time

6. *Methods Employed in Judging Time.*

Since the subjects were permitted to employ any method of judging time most serviceable to them for the purpose (except the use of a timepiece), retrospections were secured from all subjects in order to obtain some knowledge of the common methods employed. Following is a list of quotations which represent the different methods used in estimating time:

1. Estimation—
    (a) "Counted 60 to a minute."
    (b) "Imagined a second hand moving."
    (c) "Counted on style of clock ticking."
    (d) "By swaying movement."
    (e) "In my early school experience one of my teachers taught me the conception of time, i.e., she said that ordinary count, not too fast or too slow, could be safely counted as a second."

- (f) "Judged time in general intervals of 5 seconds."
- (g) "Calculated time by listening to heart-beat."
- (h) "Estimated time by regular movements of foot, estimating as nearly as possible a second between movements."
- (i) "By just wondering how many seconds I was waiting for the command to stop."
- (j) "Imagined myself the second hand of a watch."

2. Tapping—
    - (a) "Counted."
    - (b) "Estimated on standard set in Estimation Test."
    - (c) "Imagined a second hand moving."
    - (d) "Counted on style of clock ticking."
    - (e) "Counted number of taps."
    - (f) "Judged time in general intervals of 5 seconds."
    - (g) "Just guessed."
    - (h) "Found difficulty in counting while tapping because the rate of tapping is faster than counting 1 per second."
3. Cancellation—
    - (a) "Counted."
    - (b) "Guessed at random."
    - (c) "Quantity of work plus ease or difficulty."
    - (d) "Time calculated by the number of 5's cancelled."
    - (e) "Estimated time of each individual cancellation."
    - (f) "Compared the time with that of empty time."
4. Analogies—
    - (a) "On basis of guessed standard in previous tests."
    - (b) "Guessed."
    - (c) "By amount of work done."
    - (d) "Made allowance for difficulty of work."
    - (e) "By the amount of energy expended in doing the work."
    - (f) "Quantity of work done plus ease or difficulty of work."
5. Number Series Completion—
    - (a) "Chance estimate."
    - (b) "Quantity of work plus ease or difficulty."
    - (c) "On basis of mental strain involved in work."
    - (d) "By the amount of work done."
    - (e) "Amount of labor used in doing the work."
    - (f) "Compared with time in previous tests."
    - (g) "On basis of guessed standard."

A classification of the methods employed in the judgment of time is presented in Table XXIII. Of the 340 explanations of the methods employed in judging time only 20 or 5.9% are random guesses, which clearly indicates that estimation of

TABLE XXIII

METHODS EMPLOYED IN JUDGMENT OF TIME
N = 340 (68 JUDGMENTS FOR EACH FILLING

Filling	*Counting plus other Bodily Movements*		*Quantity of Performance*		*Quantity plus Accuracy of Performance*		*Random Guesses*	
	Frequency	*%*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
Estimation	66	97.1	0	0.0	0	0.0	2	2.9
Tapping	42	61.8	23	33.8	0	0.0	3	4.4
Cancellation	8	11.8	55	80.9	2	2.9	3	4.4
Analogies	0	0.0	10	14.7	53	77.9	5	7.4
Completion	0	0.0	6	8.8	55	80.9	7	10.3

Random Guesses = 20 (5.9%)

time is almost completely guided by some cue which determines the individual's judgment. In nearly every instance a certain event is the measure of the time which has elapsed. In the case of Estimation it is counting or a combined reaction of counting and some other bodily movement which is the determining factor. 97.1% of the retrospections indicate a preference for these two methods. When the filling Tapping is introduced, counting still plays a prominent part, but here we find a new factor influencing judgment. 33.8% of the judgments are based upon the number of taps in a given interval. The filling Cancellation causes a decrease in the "counting" method as determining judgment, and more stress is placed upon the quantity of work done. 80.9% of the judgments are based upon quantity of performance, and only 19.1% upon counting, guessing at random, or some other method employed during the filling Estimation. Analogies and Completion entirely eliminate counting as a means of judging time. Only 12 (8.8%) of the judgments are influenced by chance guessing, while 91.2% of the judgments are determined by quantity and difficulty of performance.

B. ELEMENTARY SCHOOL CHILDREN

1. *Effect of Age upon Estimation of Time.*

Tables XXIV to XXIX record the distributions of the judgments for intervals 20″ and 40″ conditioned by the fillings Estimation, Writing I's, Cancellation, and Constant Increments. Each Table represents a different age. Thus Table XXIV gives the distribution for 9-year-olds, Table XXV for 10-year-olds, etc. The judgments are grouped in 20″ classes.

Multi-modality is very marked in all ages. This is due, no doubt, to the fact that there is a tendency for these individuals to judge small durations of time in terms of whole minutes.

TABLE XXIV

Distribution of Judgments in 20″ Classes for All Intervals and Fillings.

	Age 9 years.							
Classes (in sec.)	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.
0- 19	6	1	10	5	23	15	24	17
20- 39	6	2	9	4	5	6	10	11
40- 59	7	3	1	3	3	3		
60- 79	7	6	18	8	11	5	7	12
80- 99	2	1			1	11		
100-119	0	1		1		0		
120-139	10	3	6	5	3	4	6	1
140-159								
160-179								
180-199	5	3	4	12	4	7	4	5
200-219			1					
220-239								
240-259	2	3		3	2	2	1	3
260-279								
280-299								
300-319	5	14	6	6	4	3	6	4
320-339								
340-359								
360-379		4	2	1		1	1	
380-399								
400-419								
420-439		6		2	1	1		
440-459								
460-479		1						
480-499	2							2
500-519								
520-539								
540-559				1		1		
560-579								
580-599								
600-619	3			4				1
620-639								
640-659								
660-679		3			1			
680-699								
700-719								
720-739							1	
740-759								
760-779								
780-799								
800-819					1			
820-839								
840-859								
860-879								
880-899								
900-919	3	4		1				1
over 920	2	5	3	4	1	1		3

TABLE XXV

DISTRIBUTION OF JUDGMENTS IN 20″ CLASSES FOR ALL INTERVALS AND FILLINGS

	AGE—10 YEARS							
Classes (in sec.)	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.
0- 19	18	3	42	14	65	41	62	46
20- 39	31	12	44	21	26	15	27	29
40- 59	24	8	1	10	1	7	5	6
60- 79	15	41	22	25	27	23	17	22
80- 99	14	9	0	9	1	13	2	1
100-119	0	0	0	2	0	0	0	0
120-139	4	13	11	16	7	19	7	15
140-159	2	3	3	5	1	1	1	0
160-179	0	0	0	0	0	0	0	0
180-199	12	11	5	6	3	4	7	5
200-219	0	1	0	0	0	0	0	0
220-239	0	0	0	0	0	0	0	0
240-259	3	2	1	7	0	4	2	1
260-279	0	1	0	1	0	0	0	0
280-299	0	0	0	0	0	0	0	0
300-319	3	18	1	8	1	3	1	5
360	1	0	0	3	0	0	0	0
420	0	0	1	0	0	1	0	0
600	1	6	0	4	0	1	0	0
660	0	1	0	0	0	0	0	0
720	1	1	0	1	0	0	0	2
1200	0	1	0	0	1	1	2	1
1800	2	0	1	0	1	0	0	1
1980	0	0	1	0	0	0	0	0
2160	1	0	0	0	0	0	0	0
2400	0	0	1	0	1	1	0	0
2640	1	0	0	0	0	0	0	0
3000	1	0	0	0	0	0	2	0
3600	1	1	1	1	0	0	0	0
5400	0	1	0	2	0	0	0	1
5940	0	1	0	0	0	0	0	0
6000	0	1	0	0	0	1	0	0

This would tend to lower the frequency of occurrence of those judgments which are not whole minutes, but fractions thereof.

Tables XXIV and XXV indicate that the range of judgments of small intervals of time is very large. Extreme judgments are a common occurrence. For 9-year-olds the judgments range from 1 second to 6,000 seconds. The same is true for 10-year-olds. For age 11, however, the judgments become less scattered, and this limitation of range of judgment remains nearly constant up to and including the 14-year level.

Table XXX shows the effect of age upon the central tendency and raw variability of judgment of time intervals 20″ and 40″. Here the Median has been selected as a measure of

TABLE XXVI

Distribution of Judgments in 20″ Classes for All Intervals and Fillings

Age—11 years

Classes (in sec.)	Estimation		Writing I's		Cancellation		Constant Increment	
	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.
0- 19	19	3	48	14	63	39	61	52
20- 39	45	17	37	22	25	27	29	19
40- 59	14	17	9	28	7	6	4	6
60- 79	18	35	11	12	14	15	10	27
80- 99	3	13	3	12	1	9	6	2
100-119	2	1		4				2
120-139	5	7	2	10	3	10	3	6
140-159	1	3		3	1	3	1	1
160-179								
180-199	4	7	5	2		4	2	1
200-219	1	1						
220-239								
240-259	1	2		1	1			
260-279		1						
280-299		1						
300-319	2	4		5		2		1
360		1	1	1	1	1		
420		1						
450				1				
600	1	2	1	1	1	1		
660	1			1				
800		1						

TABLE XXVII

Distribution of Judgments in 20″ Classes for All Intervals and Fillings

Age—12 Years

Classes (in sec.)	Estimation		Writing I's		Cancellation		Constant Increment	
	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.
0- 19	20	3	42	17	52	30	56	40
20- 39	37	16	28	26	22	23	21	28
40- 59	11	15	9	8	6	9	6	6
60- 79	15	25	7	17	6	17	2	11
80- 99	1	7	1	6	1	3	1	2
100-119		3		1		3		
120-139	3	8	4	9	3	3	4	2
140-159		2		2				1
160-179		1			1			
180-199	2	6		2	2	4	2	3
200-219								
220-239								
240-259	2	4		4		1		
260-279								
280-299								
300-319	2	3	2	1			1	

TABLE XXVIII

Distribution of Judgments in 20″ Classes for All Intervals and Fillings

Age—13 years								
Classes (in sec.)	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.
0- 19	21	4	48	19	57	32	75	48
20- 39	59	17	44	29	37	33	21	38
40- 59	18	15	12	22	10	17	10	10
60- 79	15	36	12	21	9	17	7	20
80- 99	3	20	1	8	3	5	2	4
100-119	3	4		3		2	1	
120-139	10	10	4	12	4	10	2	2
140-159		3		2		1		
160-179	1							
180-199	2	6	1	3	1	3		
200-219		3		1				
220-239								
240-259					1	1		
260-279		1				1		
280-299								
300-319		2		3				
360		1						

TABLE XXIX

Distribution of Judgments in 20″ Classes for All Intervals and Fillings

Age—14 years								
Classes (in sec.)	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.	20 sec.	40 sec.
0- 19	34	4	73	27	72	40	85	56
20- 39	52	30	36	26	39	44	35	46
40- 59	20	18	10	27	2	17	7	11
60- 79	18	33	14	28	15	18	7	16
80- 99	6	12		8	4	6	2	4
100-119		7		4				
120-139	3	11	5	7	3	9	1	4
140-159	3	4		3	1			
160-179		9						
180-199	1			5	1	2		
200-219		1				1		
220-239								
240-259		2		2				
260-279		2						
280-299								
300-319	1	2			1			1
420				1		1	1	
450		1						
600		1						

TABLE XXX

EFFECT OF AGE UPON MEDIAN AND VARIABILITY (Q) OF JUDGMENT OF TIME INTERVALS, 20″ AND 40″

A. TIME INTERVALS—20″

Age	*No. of Cases*	*Estimation*			*Writing I's*			*Cancellation*			*Constant Increment*		
		Med.	*Q*	*P. E. Med.*	*Med.*	*Q*	*P. E. Med.*	*Med.*	*Q*	*P. E. Med.*	*Med.*	*Q*	*P. E. Med.*
9	60	120.0	100.0	16.10	70.0	77.5	12.48	45.0	55.0	8.86	27.5	55.0	8.86
10	135	46.5	30.0	3.21	35.5	25.0	2.68	20.0	26.0	2.78	20.0	25.0	2.68
11	117	32.0	18.0	2.07	23.0	18.0	2.07	15.0	27.0	3.11	17.0	11.0	1.27
12	93	30.0	20.0	2.58	22.0	15.0	1.94	15.0	12.0	1.55	15.0	11.0	1.42
13	122	31.0	19.0	2.15	22.5	14.0	1.58	20.0	11.0	1.24	15.0	11.0	1.24
14	138	30.0	16.0	1.70	18.5	18.0	1.91	17.0	10.0	1.06	13.0	11.0	1.17

B. TIME INTERVALS—40″

Age	*No. of Cases*	*Estimation*			*Writing I's*			*Cancellation*			*Constant Increment*		
		Med.	*Q*	*P. E. Med.*	*Med.*	*Q*	*P. E. Med.*	*Med.*	*Q*	*P. E. Med.*	*Med.*	*Q*	*P. E. Med.*
9	60	300.0	173.5	27.93	180.0	120.0	19.32	86.0	82.0	13.20	60.0	82.5	13.28
10	135	90.0	90.0	9.63	76.0	58.0	6.21	60.0	53.0	5.67	30.0	25.0	2.68
11	117	60.0	36.0	4.14	50.0	35.0	4.03	30.0	37.0	4.26	20.0	25.0	2.88
12	93	60.0	38.0	4.90	45.0	35.0	4.52	30.0	23.0	2.97	24.0	15.0	1.94
13	122	61.0	24.0	2.71	50.0	25.0	2.83	31.0	21.0	2.37	25.0	16.0	1.81
14	138	60.0	36.0	3.81	50.0	23.0	2.44	30.0	23.0	2.44	20.0	13.0	1.38

the central tendency and Q as a measure of variability. The average has not been employed, since too much emphasis would then be placed upon the extreme judgments. Table XXXI is derived from Table XXX to indicate more clearly the effect of age upon amount of over- and under-estimation of judgments of time intervals 20″ and 40″ for the various fillings.

Table XXXI impresses us with the fact that when 20″ is selected as the time interval and Estimation as a filling, there is marked improvement in judgment of time from ages 9 to 11 years. At 11 years improvement in accuracy of judgment ceases. The slight improvement of the 12-, 13-, and 14-year-olds over the 11-year-olds is comparatively negligible. That the results indicating improvement in accuracy from ages 9 to 11 years for Estimation are reliable can be observed by

TABLE XXXI

EFFECT OF AGE UPON AMOUNT OF OVER- AND UNDER-ESTIMATION OF JUDGMENTS FOR VARIOUS FILLINGS

A. TIME INTERVAL—20″

Age	*No. of cases*	*Estimation*	*Writing I's*	*Cancellation*	*Constant Increment*
9	60	+100.0″	+50.0″	+25.0″	+7.5″
10	135	+ 26.5	+15.5	0.0	0.0
11	117	+ 12.0	+ 3.0	— 5.0	—3.0
12	93	+ 10.0	+ 2.0	— 5.0	—5.0
13	122	+ 11.0	+ 2.5	0.0	—5.0
14	138	+ 10.0	— 1.5	— 3.0	—7.0

B. TIME INTERVAL—40″

Age	*No. of cases*	*Estimation*	*Writing I's*	*Cancellation*	*Constant Increment*
9	60	+260.0″	+140.0″	+46.0″	+20.0″
10	135	+ 50.0	+ 36.0	+20.0	—10.0
11	117	+ 20.0	+ 10.0	—10.0	—20.0
12	93	+ 20.0	+ 5.0	—10.0	—16.0
13	122	+ 21.0	+ 10.0	— 9.0	—15.0
14	138	+ 20.0	+ 10.0	—10.0	—20.0

The + sign indicates overestimation; the — sign denotes underestimation.

comparing the differences between the Medians of the judgments for these ages and their corresponding P.E.'s recorded in Table XXXII. For the 40″ interval the same relationship appears except that the age differences (from 9 to 11 years) are more marked. An observation of Table XXXI also reveals the fact that the greatest amount of improvement occurs between the 9- and 10-year levels. Thus at age 9 the amount of overestimation of an objective time interval of 20″ is 100″. For the 10-year level the amount of overestimation is only 26.5″. Thus there is a decrease in overestimation of 73.5″ when we compare ages 9 and 10. A comparison of the 10- and 11-year-olds reveals a difference in amount of overestimation of only 14.5″ (26.5″ — 12.0″). When we examine the results for the objective interval of 40″ for the filling Estimation, we find the same rapid improvement in accuracy of judgment of the 10-year-olds over the 9-year-olds. Age 10 denotes an increase in accuracy of judgment of 210″ (260.0″ — 50.0″), as compared with age 9, while the 11-year-olds show an improvement of only 30″ (50″ — 20″) when compared with age 10. The general tendency, therefore, is for the increase in accur-

TABLE XXXII

DIFFERENCES AND P.E.'S OF THE DIFFERENCES BETWEEN AMOUNTS OF OVERESTIMATION OF TIME INTERVALS 20″ AND 40″ WHEN A COMPARISON OF AGES IS MADE

A. TIME INTERVAL—20″

Compared Ages	*Estimation*		*Writing I's*		*Cancellation*	
	Diff.	*P. E. Diff.*	*Diff.*	*P. E. Diff.*	*Diff.*	*P. E. Diff.*
9 and 10	+73.5″	16.41	+34.5″	12.78	+25.0″	9.28
10 and 11	+14.5	3.81	+12.5	3.38	+ 5.0	4.17

B. TIME INTERVAL—40″

Compared Ages	*Estimation*		*Writing I's*		*Cancellation*	
	Diff.	*P. E. Diff.*	*Diff.*	*P. E. Diff.*	*Diff.*	*P. E. Diff.*
9 and 10	+210.0″	29.54	+104.0″	20.29	+26.0″	14.36
10 and 11	+ 30.0	10.48	+ 26.0	7.40	+10.0	7.09

The + sign indicates that the amount of overestimation of the first member of the pair is greater than the amount of overestimation of the second member.

acy of judgment of the time intervals 20″ and 40″ to become smaller up to age 11 from whence improvement approaches zero.

When Writing I's conditions judgment, we observe the same tendency toward improvement in accuracy of judgment up to the 11-year level. Table XXXI indicates greater improvement in accuracy for age 10 as compared with age 9 than is the case with the 11-year-olds when compared with the 10-year level. Thus judgment of the time intervals 20″ and 40″ in conventional units appears to reach its fullest development at age 11. This is true for both Estimation (a form of "unfilled time") and Writing I's (a form of motor activity).

The filling Cancellation reveals another important fact. For this type of filling increase in accuracy of judgment ceases at the age of 10 years. Thus the change from a motor act (Writing I's) to a sensori-motor act (Cancellation) results in less differentiation in ability to judge time among the ages 9 to 14 years.

When the filling Constant Increments is introduced, the 9-year-olds judge small intervals of time as accurately as the 14-year-olds (Table XXXI). For age 9 the amount of over-

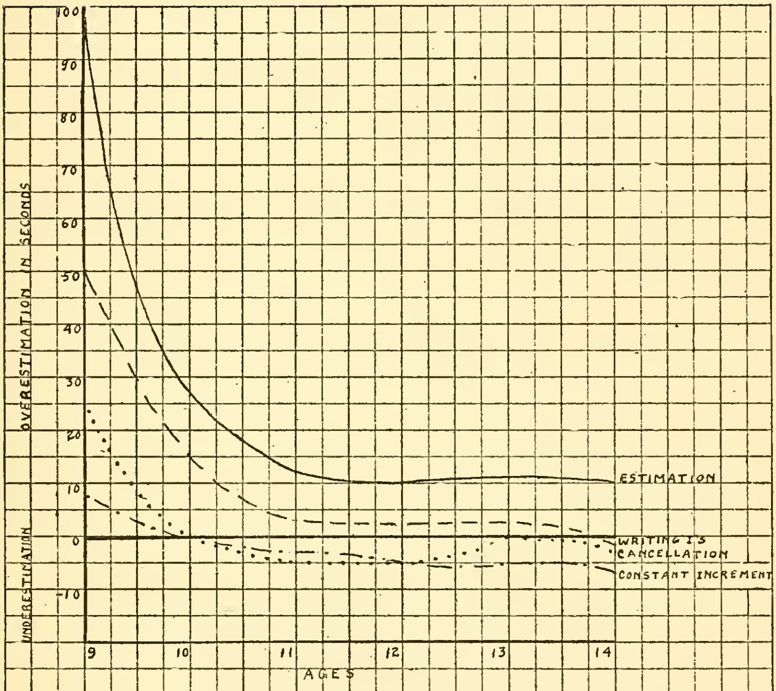

FIG. 2 — EFFECT OF AGE UPON AMOUNT OF OVER— AND UNDER-ESTIMATION OF JUDGMENTS FOR VARIOUS FILLINGS. TIME-INTERVAL — 20"

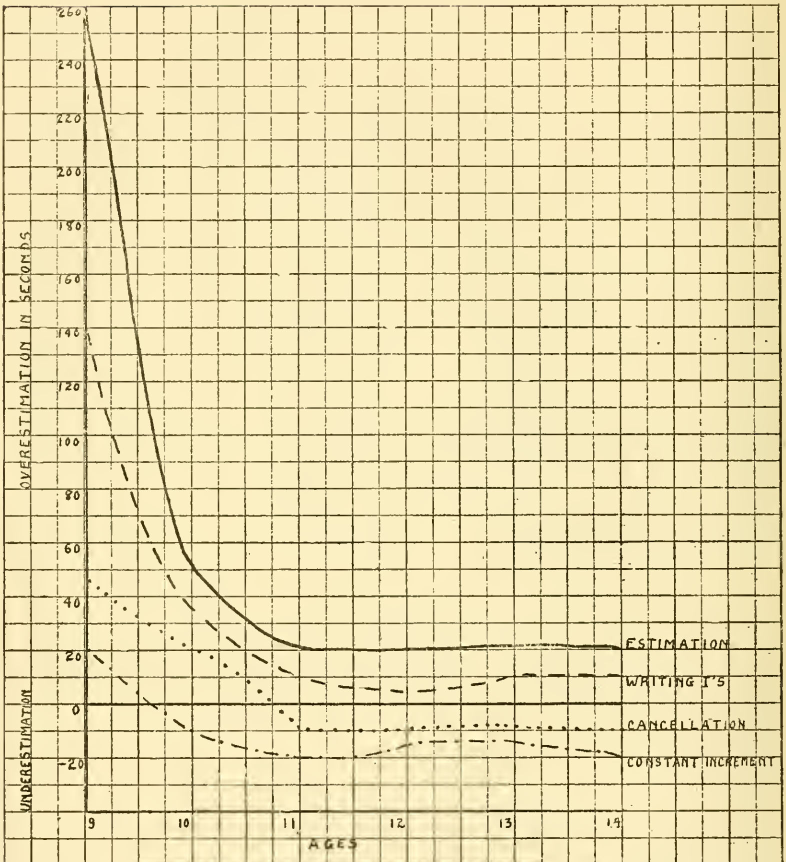

FIG. 3. — EFFECT OF AGE UPON AMOUNT OF OVER — AND UNDER-ESTIMATION OF JUDGMENTS FOR VARIOUS FILLINGS. TIME-INTERVAL — 40"

estimation of a 20″ interval is 7.5″, while for age 14 there is an underestimation of 7.0″. Although the former is an overestimation and the latter an underestimation, the degree of accuracy in both cases is nearly the same. When the intervening ages are compared for this filling, there appears no significant difference in degree of accuracy of judgment. Observing the results for the objective interval, 40″, we again note that the 9-year-olds and 14-year-olds are equally accurate except that the former overestimate while the latter underestimate this objective interval.

The results for Table XXXI are represented graphically in Figures 2 and 3. Figure 2 shows that for the fillings Estimation and Writing I's there is a decrease in amount of overestimation of the 20″ interval until the 11-year level is reached. Beyond this age the curve is nearly a straight line. For Cancellation there is an improvement in accuracy up to age 10, beyond which there is very little variation in judgment. The filling Constant Increments indicates no significant improvement in accuracy of judgment among the ages, the curve beginning with a slight overestimation and terminating in an underestimation of approximately equal magnitude. An analysis of Figure 3 indicates results very similar to those of Figure 2. Hence, we can infer from a comparison of the results for Tapping, Cancellation, and Constant Increments that the higher the level of human behavior which functions during a small time interval the greater is the tendency towards equality in accuracy of judgment of this interval between the ages 9 to 14 years.

Figures 2 and 3 also represent graphically that with a change in age from 9 to 11 there is a decrease in the amount of overestimation for the fillings Estimation and Writing I's. The same tendency persists in the case of the fillings Cancellation and Constant Increments, although here there is a shift from an overestimation to an actual underestimation. In any event, the change with age from 9 to 11 is a change in the direction of underestimation.

Table XXXIII records the effect of age upon the Variability Quotient of the judgments of the time intervals, 20″ and 40″. An analysis of Table XXXIII reveals the fact that for Estimation there is a decrease in the variability of the judgments until the 11-year level is reached. Among the ages 11 to 14 there is no appreciable difference in variability. For the filling

Writing I's there is a decrease in variability up to age 10. Here we find that for the 20″ interval the 14-year-olds are even slightly more variable than the 10-year-olds, although for the 40″ interval there is a marked decrease in the variability. For Cancellation there is no significant difference in amount of variability among the ages 12 to 14 when the intervals 20″ and 40″ are considered. For the filling Constant Increments the 9-year-olds show much greater variability of judgment than ages 10 to 14. From ages 11 to 14 there is no significant decrease in the variability.

TABLE XXXIII

EFFECT OF AGE UPON VARIABILITY QUOTIENT* OF JUDGMENTS OF TIME INTERVALS, 20″ AND 40″

Age	*No. of Cases*	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
		20″	40″	20″	40″	20″	40″	20″	40″
9	60	9.13″	10.02″	9.26″	8.94″	8.19″	8.84″	10.49″	10.64″
10	135	4.40	9.47	4.20	6.65	5.81	6.84	5.59	4.56
11	117	3.18	4.64	3.75	4.95	6.97	6.75	2.66	5.59
12	93	3.65	4.90	3.20	5.21	3.10	4.19	2.84	3.06
13	122	3.41	3.07	2.95	3.53	2.46	3.77	2.84	3.20
14	138	2.92	4.64	4.30	3.25	2.42	4.19	3.04	2.90

*The variability (Q) divided by the square root of the Median.

Table XXXIIIa represents the percentage frequencies of occurrence of judgments which are equal to or greater than four times the objective time intervals, 20″ and 40″. These may be called extreme judgments since for the fillings Estimation and Constant Increments and the objective time interval 20″ the 14-year-olds exhibit only 10.1% and 2.9% respectively, of these judgments. When the results for the 40″ interval are examined, we find that for age 14 the percentage frequency of these judgments is 13.0 for Estimation and 0.7 for Constant Increments. Table XXXIIIa clearly indicates the effect of age upon these extreme judgments for the various fillings. Thus, for the filling Estimation there is a marked decrease in the percentage frequency of the extreme judgments up to age 12. This is true for both objective time intervals. Observing the results for Writing I's, we find no significant decrease in the percentage of extreme judgments beyond age 12. Considering both intervals for the fillings Cancella-

TABLE XXXIIIa

EFFECT OF AGE UPON THE PERCENTAGE FREQUENCY OF OCCURRENCE OF JUDGMENTS WHICH ARE EQUAL TO OR GREATER THAN FOUR TIMES THE OBJECTIVE TIME INTERVALS, 20″ AND 40″

Age	*No. of Cases*	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
		20″	40″	20″	40″	20″	40″	20″	40″
9	60	56.6	71.6	36.6	56.6	30.0	26.6	31.6	31.6
10	135	34.8	34.0	19.2	24.4	11.8	11.8	17.7	11.8
11	117	17.9	17.9	10.2	10.2	6.8	6.8	10.2	1.7
12	93	10.7	15.0	7.5	7.5	7.5	5.3	8.6	3.2
13	122	15.5	10.7	4.9	5.7	7.4	4.1	4.1	0.0
14	138	10.1	13.0	3.6	5.7	7.2	2.9	2.9	0.7

TABLE XXXIIIb

EFFECT OF AGE UPON THE PERCENTAGE FREQUENCY OF OCCURRENCE OF JUDGMENTS WHICH ARE EQUAL TO OR LESS THAN ONE-FOURTH OF THE OBJECTIVE TIME INTERVALS, 20″ AND 40″

Age	*No. of Cases*	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
		20″	40″	20″	40″	20″	40″	20″	40″
9	60	5.0	5.0	16.6	10.0	25.0	25.0	20.0	31.6
10	135	3.0	1.4	14.0	6.6	21.4	18.5	17.8	23.7
11	117	2.5	0.0	17.0	6.8	15.3	16.2	17.9	28.2
12	93	0.0	1.0	16.1	6.4	19.3	15.0	18.2	29.0
13	122	0.8	1.6	13.1	8.2	13.9	15.5	14.7	22.1
14	138	2.1	0.7	16.0	13.0	13.7	14.5	18.8	19.5

TABLE XXXIIIc

EFFECT OF AGE UPON THE SUM TOTAL OF THE PERCENTAGE FREQUENCIES OF JUDGMENTS WHICH ARE BOTH POSITIVE AND NEGATIVE EXTREMES COMPOSITE OF TABLES XXXIIIA AND XXXIIIB

TIME INTERVALS, 20″ AND 40″

Age	*No. of Cases*	*Estimation*		*Writing I's*		*Cancellation*		*Constant Increment*	
		20″	40″	20″	40″	20″	40″	20″	40″
9	60	61.6	76.6	53.2	66.6	55.0	51.6	51.6	63.2
10	135	37.8	35.4	33.2	31.0	33.2	30.3	35.5	35.5
11	117	20.4	17.9	27.2	17.0	22.1	23.0	28.1	29.9
12	93	10.7	16.0	23.6	13.9	26.8	20.3	26.8	32.2
13	122	16.3	12.3	18.0	13.9	21.3	19.6	18.8	22.1
14	138	12.2	13.7	19.6	18.7	20.9	17.4	21.7	20.2

tion and Constant Increments it would be reasonable to conclude that little, if any, difference exists in the percentage frequency of occurrence of these extreme judgments among the ages 11 to 14. A close observation of Table XXXIIIa would lead to the inference that there is a general tendency for the percentage of extreme judgments to decrease up to about the 11- or 12-year level. From here on there is no definite tendency for the percentage of extreme judgments to decrease.

Table XXXIIIb gives the percentage frequencies of the judgments which are equal to or less than one-fourth of the objective time intervals 20″ and 40″. Here we find that with the exception of the filling Writing I's there is a slight tendency for age 9 to give a greater percentage of negative extreme judgments than for ages 10 to 14. Among the latter ages there is no marked tendency for a decrease in the percentage of extreme judgments with an increase in age. The total percentages of positive and negative extreme judgments for each age, filling, and time interval are expressed in Table XXXIIIc. Since the percentage of negative extreme judgments is not noticeably affected by an increase in age, the results in Table XXXIIIc practically agree with those in Table XXXIIIa. Taking both positive and negative extreme cases into consideration, it would be reasonable to conclude from Table XXXIIIc that there is a marked decrease in the percentage of extreme judgments from ages 9 to 11 or 12, while there appears no appreciable decrease in the percentage of extreme judgments from ages 11 or 12 to 14.

2. *Effect of Type of Filling upon Estimation of Time*

The effect of the type of filling upon the central tendencies of the judgments of the intervals 20″ and 40″ is indicated in Table XXXIV. The first column contains the various fillings conditioning judgment; the next column records the Medians for the combined ages 9 to 14 years (665 cases); the third column records the variabilities of the distributions expressed in terms of Q (semi-quartile range), while the last column lists the probable errors of the Medians. In Table XXXIV we are mainly concerned with the Medians of the judgments. The actual Variability Quotients, for the purpose of comparison, appear in Table XXXVI.

An interesting relationship is clearly observed in Table

XXXIV. The influence of the different fillings upon judgment of time is very marked. The filling Estimation causes the objective time intervals, 20″ and 40″, to be judged as 35.0″

TABLE XXXIV

MEDIANS, MEDIAN DEVIATIONS, AND PROBABLE ERRORS OF THE MEDIANS FOR EACH FILLING AND INTERVALS 20 AND 40 SECONDS

COMBINED RESULTS AND AGES 9-14 YEARS, N = 665

	Fillings	*Med.*	*Q*	*P.E.*
20″	Estimation	35.0″	18.5″	0.89″
	Writing I's	23.5	18.0	0.86
	Cancellation	17.5	18.5	0.89
	Constant Increment	15.0	11.0	0.53

	Fillings	*Med.*	*Q*	*P.E.*
40″	Estimation	60.0″	38.0″	1.82″
	Writing I's	50.5	35.5	1.70
	Cancellation	31.5	26.5	1.27
	Constant Increment	25.0	20.0	0.96

TABLE XXXV

DIFFERENCES AND PROBABLE ERRORS OF THE DIFFERENCES BETWEEN MEDIANS OF DISTRIBUTIONS OF JUDGMENTS OF INTERVALS, 20″ AND 40″, WHEN A COMPARISON OF FILLINGS IS MADE

COMBINED RESULTS FOR AGES 9-14 YEARS

	Compared Fillings	*Diff.*$_{\text{med}}$	*P.E.*$_{\text{diff}}$
20″	Estimation and Writing I's	+11.5″	1.24″
	Estimation and Cancellation	+17.5	1.26
	Estimation and C. I.	+20.0	1.03
	Writing I's and Cancellation	+ 6.0	1.24
	Writing I's and C. I.	+ 8.5	1.01
	Cancellation and C. I.	+ 2.5	1.03

	Compared Fillings	*Diff.*$_{\text{med}}$	*P.E.*$_{\text{diff}}$
40″	Estimation and Writing I's	+ 9.5″	2.49″
	Estimation and Cancellation	+28.5	2.22
	Estimation and C. I.	+35.0	2.06
	Writing I's and Cancellation	+19.0	2.12
	Writing I's and C. I.	+25.5	1.95
	Cancellation and C. I.	+ 6.5	1.59

The plus sign indicates that the Median of the judgments conditioned by the first filling of each pair is greater than the Median of the judgments of the time intervals corresponding to the second member (filling) of the pair selected.

and 60.0″, respectively. These estimates are larger than those obtained for the remaining fillings. Writing I's, which represents a type of motor activity, gives next highest judgment. The intervals, 20″ and 40″, are judged as 23.5″ and 50.5″, respectively. The P.E.'s of the Medians clearly indicate that these overestimations are reliable. The fillings Cancellation and Constant Increments (C. I.) cause underestimations. However, the amount of underestimation is greater when the filling Constant Increments conditions judgment, as evidenced by the median judgments 15.0″ and 25.0″ as compared with 17.5″ and 31.5″ for Cancellation. The reliability of this difference in judgment is indicated in Table XXXV. Thus we observe a definite relationship between type of activity and judgment of time. Unfilled time (Estimation) and motor activity (Tapping) cause overestimation of these time intervals, while sensori-motor (Cancellation) and mental activity (Constant Increments) cause underestimation of judgment. Comparing the effects of sensori-motor and mental activity, we find that the latter causes greater underestimation. Also, although both unfilled time and motor activity cause overestimation of time, the amount of overestimation is greater for unfilled time. These results lead to the following conclusions:

1. Unfilled time, represented by Estimation, is overestimated.

2. The higher the level of human behavior, the greater is the tendency for underestimation of small durations of time.

Table XXXV gives the differences between the Medians of the judgments of the objective time intervals with their corresponding P.E.'s. Each difference is at least twice its P.E., thus indicating a fair degree of reliability.

The effect of the type of filling upon variability of judgment is shown in Table XXXVI. It is clear that if a true compari-

TABLE XXXVI

EFFECT OF DIFFERENT FILLINGS UPON THE VARIABILITY QUOTIENTS (V) OF JUDGMENTS OF TIME INTERVALS, 20″ AND 40″. COMBINED RESULTS FOR AGES 9 TO 14 YEARS

n = 665

Filling	*V 20*	*V 40*
Estimation	3.12″	4.90″
Writing I's	3.72	5.00
Cancellation	4.42	4.72
Constant Increment	2.84	4.00

son of the variabilities is to be made the central tendencies should be taken into consideration. Each gross variability is divided by the square root of the Median. When the resulting Variability Quotients (V) are compared, we find no significant relationship between type of activity and variability of judgment.

3. Relation between Estimation of Time and Amount of Performance for Various Fillings.

Since individual differences exist in amount of performance during the time interval as well as in judgment of time, the following question immediately arises: What is the relation between the amount of work done during a given time interval and the judgment of that interval? Does A, who overestimates time, produce more work during the interval than B, whose tendency is to underestimate time? This question can be answered by correlating each individual estimate with the corresponding amount of performance during the given interval.

Table XXXVII gives the relation between estimation of time and amount of performance. The coefficients of correlation were determined by correlating the individual estimates with the corresponding scores obtained in the particular task during the interval. In Writing I's, the number of i's completed during the interval was the score. For Cancellation the number of 5's cancelled determined the individual's amount of performance. Similarly, the number of additions in the Constant Increment Test represented the subject's score for this type of work. The coefficients were determined for each age. The following formula, by Pearson, was employed in determining the coefficients of correlation:

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2}\sqrt{\Sigma y^2}}$$

Table XXXVII clearly indicates that there is no significant relation between magnitude of judgment of small durations of time and amount of performance. The individual with higher estimations of time does not necessarily perform more work during the interval. All the coefficients hover about zero, some being slightly positive, others slightly negative.

TABLE XXXVII

RELATION BETWEEN ESTIMATION OF TIME AND AMOUNT OF PERFORMANCE FOR VARIOUS FILLINGS

A

ESTIMATION OF TIME AND RESULTS OF CONSTANT INCREMENT TEST

Age	*No. of cases*	*r*	*P.E.*
9	78	—.01	.08
10	135	+.05	.06
11	117	—.13	.06
12	93	+.02	.07
13	122	+.12	.06
14	138	—.12	.06

B

ESTIMATION OF TIME AND RESULTS OF CANCELLATION TEST

Age	*No. of cases*	*r*	*P.E.*
9	78	—.18	.07
10	135	+.09	.06
11	117	+.06	.06
12	93	+.03	.07
13	122	—.01	.06
14	138	+.02	.06

C

ESTIMATION OF TIME AND WRITING I'S

Age	*No. of cases*	*r*	*P.E.*
9	78	+.04	.08
10	135	+.13	.06
11	117	+.03	.06
12	93	+.06	.07
13	122	+.15	.06
14	138	—.05	.06

4. *Difference in Estimation of Time between Elementary School Boys and University Students of the Same Sex.*

Thus far the results for ages 9 to 14 and those for undergraduate and graduate students have been treated separately. An attempt will now be made to compare these groups with regard to accuracy of judgment, the tendency for over- and under-estimation, and variability. Both the elementary school boys and the university students estimated the 20″ interval conditioned by the fillings Estimation and Cancellation. However, the two experiments differed somewhat in methodology. The university students were requested to express their judgments in terms of seconds, while the estimates of the school children were not restricted to any definite standard unit.

Table XXXVIII gives the distribution of the judgments for the university students. The central tendencies and variabilities for all ages and those for undergraduate and graduate students are recorded in Table XXXIX. The effect of age upon judgment of time has already been discussed above. For the filling Estimation we found no appreciable difference between the Medians of the judgments when ages 11 to 14 were compared. However, when we compare the Medians of the judgments for ages 11 to 14 with that of the student group, we find a marked difference in accuracy of judgment, as well as in the magnitude of the central tendency. For the filling Estimation the median judgments for ages 11 to 14 range from 30″ to 32″, while for the university group the Median is only 18″.

TABLE XXXVIII

DISTRIBUTION OF JUDGMENTS IN 10″ CLASSES FOR UNDERGRADUATE AND GRADUATE STUDENTS. TIME INTERVAL —20″. N = 46.

Classes in Seconds	*Estimation*	*Cancellation*
0 — 9	5	13
10 — 19	24	17
20 — 29	11	9
30 — 39	4	4
40 — 49	0	3
50 — 59	1	
60 — 69	1	

TABLE XXXIX

MEDIANS, VARIABILITIES (Q) AND P. E.'S OF THE MEDIANS OF THE JUDGMENTS OF THE TIME INTERVAL 20″ FOR AGES 9 TO 14 AND UNDERGRADUATE AND GRADUATE STUDENTS

Age	*No. of Cases*	*Estimation*			*Cancellation*		
		Med.	Q	P. E.$_{\text{med}}$	Med.	Q	P. E.$_{\text{med}}$
9	60	120	100.0	16.10	45.0	55.0	8.86
10	135	46.5	30.0	3.21	20.0	26.0	2.78
11	117	32.0	18.0	2.07	15.0	27.0	3.11
12	93	30.0	20.0	2.58	15.0	12.0	1.55
13	122	31.0	19.0	2.15	20.0	11.0	1.24
14	138	30.0	16.0	1.70	17.0	10.0	1.06
Undergraduate and Graduate Students, Ages 17 to 42.	46	18.0	7.5	1.37	14.5	7.5	1.37

Thus, for the 20″ interval the students display a tendency toward underestimation. Numerically, this change in the direction of underestimation is 60% of the objective time interval, when compared with the 14-year level. The difference in accuracy of judgment between these groups is also significant. The difference between the Median of the judgments for the university group and the objective time interval is only 2.0″, while the 14-year-olds indicate a Median which is 10″ distance from the objective interval. The P.E. of the difference between the Medians of the groups is 2.18, thus indicating a fair degree of reliability. When the filling Cancellation is considered, we find no significant difference in the central tendency of the judgments among ages 10 to 14, and the university group. For example, the difference between the central tendencies of the judgments for age 11 and the university group is only 0.5″ with a P.E. of 3.40. Comparing the results for age 14 with those for the students, we obtain a difference in central tendency of 2.5″ with a corresponding P.E. of 1.73.

A comparison of the Variability Quotients of the judgments of the student group with those of the school children indicates that the latter are more variable for both the fillings Estimation and Cancellation. The Variability Quotient of the judgments for the university group, when Estimation is introduced as a filling, is 1.76 as compared with Variability Quotients ranging from 2.92 to 9.13 for the school group (Table XXXIII). For Cancellation the Variability Quotient of the judgments of the students is 1.97 which is again somewhat lower than those for ages 11 to 14, which range from 2.42 to 8.19.

VI. SUMMARY AND CONCLUSIONS

A. Undergraduate and Graduate Students.

1. Estimation of small durations of time is greatly influenced by the tendency for the numerals 0 and 5 to appear more frequently as final digits than any other numeral. The probability of occurrence of 0 and 5 as final digits of the judgments is 0.714, and that of final digits other than 0 and 5 is 0.286.

2. The probability of occurrence of 0 as a final digit of the judgments is 0.424, and that of 5 is 0.29, the difference between these probabilities being 14.7 times its S.E. That the obtained probabilities for the digits 0 or 5 are reliable as regards errors of simple sampling is easily demonstrated by the fact that the theoretical probability of the occurrence of any one of the ten digits in a final position is 0.10 with an S.E. of 0.004.

3. The probability of the judgments being even numbers is 0.611 as compared with 0.389 for odd numbers. When the influence of the tendency for most judgments to end in 0 or 5 is eliminated, the probability for even judgments is 0.655 and for odd judgments 0.345, the difference between the two probabilities being 17.2 times its S.E.

4. The frequency of occurrence of judgments ending in 0 and 5 tends to depend upon the level of behavior which functions during the time interval. There is a tendency for the higher levels of behavior to cause larger frequencies of judgments ending in 0 and 5. Thus there is a tendency for the fillings Estimation and Tapping to yield lesser frequencies of judgments ending in 0 and 5 than Analogies and Number Series Completion.

5. There is no significant indication that the frequency of occurrence of correct judgments of small durations of time is influenced by the type of filling employed.

6. The percentage frequency of occurrence of correct judgments for all fillings and time intervals is 3.77.

7. The estimates of small durations of time are lower for men than for women. This tendency is very marked for all fillings. The males underestimate time for all fillings whereas

the females tend to overestimate time for the fillings Estimation, Tapping, and Cancellation, and to underestimate time for the fillings Analogies and Number Series Completion. The underestimations of the males for the latter two fillings, however, are significantly greater than those for the females.

8. Great individual differences in estimation of time exist for all intervals and fillings. This is evidenced by the fact that the Median Deviation for the lowest median estimate, which is 10.0 seconds, is 5.0 and the Median Deviation for the highest median judgment, which is 33.5 seconds, is 11.5. The distributions are markedly skewed toward the positive end.

9. Estimation of small durations of time is influenced by the level of behavior which functions during a given time interval. The higher the level of behavior during a given time interval the greater is the tendency for underestimation, and vice versa the lower the level of behavior the less is the tendency for underestimation and the greater is the tendency for overestimation. Thus the filling Tapping consistently yields overestimation for all time intervals ranging from 15 to 30 seconds. The fillings Analogies and Number Series Completion consistently yield underestimations whereas the filling Cancellation also yields underestimations but lower than those obtained with Analogies and Completion. The filling Cancellation seems to fall between Tapping on the one hand, and Analogies and Number Series Completion on the other, with regard to the factors of over- and under-estimation. The filling Estimation does not differ significantly from the filling Tapping as regards overestimation. Hence it would seem that there is no sharp line of demarcation between estimation of unfilled and filled time.

10. For the intervals 15 to 30 seconds there appears to be no definite relation between the type of filling and the Variability Quotient, the variability divided by the square root of the central tendency.

11. With fillings yielding underestimations of time, there is a highly significant positive correlation between the magnitude of the objective time interval and the amount of underestimation for a given group. That is, within the limits of the time intervals selected for this study, increased durations of time tend to be accompanied by an increase in the errors of the judgments to the extent expressed by the coefficients of correlation ranging from +.83 to +.89. In the case of fillings

resulting in overestimations there seems to be no significant correlation between the magnitude of the objective time interval and the amount of error in the judgment. When the actual amounts of over- and under-estimation are transformed into per cents of the objective time there is a negative relation between the per cent of overestimation and the length of the objective interval, as indicated by the coefficients of correlation —.48 and —.54. When fillings cause underestimation of time there is a positive relation between the per cent of underestimation and the length of the objective time to the extent expressed by the coefficients ranging from .61 to .71.

12. Taking the retrospections of the subjects as a criterion for determining the methods employed in judging time, we find that there is a marked tendency for counting and other bodily movements to decrease and for the utilization of quantity and difficulty of performance to increase with the rise in the level of behavior. The frequency of random guesses is relatively small, being only 5.9% of the total number of retrospections, thus indicating that estimation of time is generally guided by some definite event which determines judgment.

B. Elementary School Children.

1. For ages 9 to 14, the effect of age upon estimation of small durations of time depends upon the level of behavior which functions during the time interval. The higher the level of behavior operating during the objective time interval the greater is the tendency for equality of accuracy of judgment among the ages. Thus, when the filling Writing I's (a type of motor activity) functions during the interval, there is a decrease in the amount of overestimation of the objective time intervals 20 and 40 seconds up to and including the 11-year level. The filling Cancellation, a sensori-motor function, causes increase in accuracy of judgment of these intervals to cease at age 10, while the filling Constant Increments causes all ages to judge time with nearly an equal degree of accuracy. The influence of the filling Estimation, a type of unfilled time, is similar to that of Writing I's in causing accuracy of judgment of these durations of time to cease at the 11-year level.

2. With the change in age from 9 to 11 there is a decrease in the magnitude of the central tendency of the judgments and

this decrease results in actual underestimation when the filling acts in the same direction.

3. The effect of age upon the Variability Quotient of the judgments depends upon the type of filling employed. For the filling Estimation there is a tendency for the Variability Quotient of the judgments to decrease until the 11-year level is reached. Writing I's causes a significant decrease in the variability up to age 10. The filling Cancellation gives no marked difference in amount of variability among the ages 12 to 14, while for the filling Constant Increments age 9 gives greater variability of judgment than ages 10 to 14.

4. There is a marked tendency for the per cent of extreme judgments to decrease up to age 11 or 12, and from there on there appears no significant decrease in extreme estimates with a change in age.

5. Small durations of unfilled time, represented by the filling Estimation, are overestimated.

6. The higher the level of behavior which functions during the objective time interval the greater is the tendency for underestimation and the less is the tendency for overestimation for a given group. When the filling Writing I's conditions judgment there is an overestimation of these intervals. On the other hand, the fillings Cancellation and Constant Increments cause underestimation of time, this underestimation being greater for the latter filling.

7. For the intervals 20 and 40 seconds there seems to be no definite relation between the level of behavior and the Variability Quotient.

8. There is no significant relation between amount of performance of a certain task during a given small time interval and the magnitude of the judgment of that interval for a given group. This is indicated by the extremely low coefficients for the fillings Writing I's, Cancellation, and Constant Increments.

9. The difference in accuracy of judgment of small durations of time between a group of boys, ages 11 to 14, and university students depends upon the type of filling employed. For the filling Estimation, which represents unfilled time, there is a marked increase in accuracy of judgment in favor of the students, but when the filling Cancellation conditions judgment the estimates of ages 11 to 14 are about as accurate as those of the university group.

APPENDIX

Samples of tests utilized in this study.

1. Analogies.
2. Number Series Completion.
3. Cancellation.
4. Constant Increment.

For the fillings Estimation, Tapping and Writing I's no standard forms were, of course, necessary.

1. ANALOGIES.

sky—blue :: grass— TABLE *GREEN* WARM BIG
SAMPLES fish—swims :: man— PAPER TIME *WALKS* GIRL
day—night :: white— RED *BLACK* CLEAR PURE

In each of the lines below, the first two words are related to each other in some way. What you are to do in each line is to see what the relation is between the first two words, and underline the word in capitals that is related in the same way to the third word. Begin with the first one and mark as many sets as you can before time is called.

finger—hand :: toe— BOX FOOT DOLL COAT
dismal—dark :: cheerful— LAUGH BRIGHT HOUSE GLOOMY
sit—chair :: sleep— BOOK TREE BED SEE
hope—cheer :: despair— GRAVE REPAIR DEATH DEPRESSION
skirts—girl :: trousers— BOY HAT VEST COAT
fear—anticipation :: regret— VAIN MEMORY EXPRESS RESIST
December—Christmas :: November— MONTH THANKSGIVING DECEMBER EARL
clock—time :: thermometer— COLD WEATHER TEMPERATURE MERCURY
above—top :: below—ABOVE BOTTOM SEA HANG
mountain—valley :: genius—IDIOT WRITE THINK BRAIN
spoon—soup :: fork— KNIFE PLATE CUP MEAT
square—cube :: circle— LINE ROUND SQUARE SPHERE
bird—song :: man— SPEECH WOMAN BOY WORK
blow—anger :: caress— WOMAN KISS CHILD LOVE
corn—horse :: bread— DAILY FLOUR MAN BUTTER
truth—gentleman :: lie— RASCAL LIVE GIVE FALSEHOOD
sweet—sugar :: sour— SWEET BREAD MAN VINEGAR
music—noise :: harmonious— EAR ACCORD VIOLENT DISCORDANT
devil—bad :: angel— GABRIEL GOOD FACE HEAVEN
complex—simple :: hard— BRITTLE MONEY EASY WORK
Edison—phonograph :: Columbus— AMERICA WASHINGTON SPAIN OHIO
darkness—stillness :: light— MOONLIGHT SOUND SUN WINDOW

cannon—rifle :: big— BULLET GUN ARMY LITTLE
a—b :: c— E B D LETTER
engineer—engine :: driver— HARNESS HORSE PASSENGER MAN
peace—happiness :: war— GRIEF FIGHT BATTLE EUROPE
wolf—sheep :: cat— FUR KITTEN DOG MOUSE
people—house :: bees— THRIVE STING HIVE THICK
officer—private :: command— ARMY GENERAL OBEY REGIMENT
succeed—fail :: praise— LOSE FRIEND GOD BLAME
hunter—gun :: fisherman— FISH NET BOLD WET
mayor—city :: general— PRIVATE NAVY ARMY SOLDIER
cold—heat :: ice— STEAM CREAM FROST REFRIGERATOR
polite—impolite :: pleasant— AGREEABLE DISAGREEABLE MAN FACE
uncle—nephew:: aunt— BROTHER SISTER NIECE COUSIN
abundant—cheap :: scarce— COSTLY PLENTIFUL COMMON GOLD
framework—house :: skeleton— BONES SKULL GRACE BODY
blonde—brunette :: light— HOUSE ELECTRICITY DARK GIRL
breeze—cyclone :: shower— BATH CLOUDBURST WINTER SPRING
pitcher—milk :: vase— FLOWERS PITCHER TABLE POTTERY
dog—bark :: cat— CHAIR MEW FIRE HOUSE
historian—facts :: novelist— FICTION DICKENS WRITER BOOK
foot—man :: hoof— CORN TREE COW ROE
imitate—copy :: invent— STUDY EDISON MACHINE ORIGINAL
dog—puppy :: cat— KITTEN DOG TIGER HORSE
10—100 :: 1000— MONEY 10000 2000 WEALTH
wash—face :: sweep— CLEAN ROOM FLOOR STREET
education—ignorance :: wealth— POVERTY RICHES HEALTH COMFORT
door—house :: gate— SWING HINGES YARD FENCE
order—confusion :: peace— PACT TREATY WAR NAVY
water—fish :: air— SPARK MAN BLAME BREATHE
establish—abolish :: begin— WORK YEAR END COMMERCE
white—black :: good— TIME CLOTHES MOTHER BAD
yes—no :: affirmative— WIN DEBATE DENY NEGATIVE
boy—man :: lamb—SHEEP DOG SHEPHERD WOOL
tear—laughter :: sorrow— JOY DISTRESS FUNERAL SAD
roof—house :: hat— BUTTON SHOE STRAW HEAD
hospital—patient :: prison— CELL CRIMINAL BAR JAIL
camp—safe :: battle— WIN DANGEROUS FIELD FIGHT
esteem—friends :: despise— FORSAKE DETEST ENEMIES PEOPLE
straw—hat :: leather— SHOE BARK COAT SOFT
airplane—air :: submarine— DIVE ENGINE SHIP WATER
pan—tin :: table— CHAIR WOOD LEGS DISHES
terrier—dog :: Jersey— CITY COW HORSE STATE
left—right :: west— SOUTH DIRECTION EAST NORTH
engineer—chauffeur :: locomotive—IRON STOCK ENGINE AUTO
floor—ceiling :: ground— EARTH SKY HILL GRASS
revolver—man :: sting— GUN HURT BEE HAND
cold—ice :: heat— WET COLD STEAM STARS

ocean—pond :: deep—SEA WELL SHALLOW STEEP
hat—head :: thimble—SEW CLOTH FINGER HAND
arteries—body :: railroad— COUNTRY TRAIN CROSSING ACCIDENT
Monday—Tuesday :: Friday— WEEK THURSDAY DAY SATURDAY
knitting—girls :: carpentry— TRADE HOUSES BOYS LUMBER
lead—bullet :: gold— PAPER COIN SILVER COPPER
suitcase—clothing :: purse— PURCHASE MONEY STRING STOLEN
skin—body:: bark— TREE DOG BITE LEAF
man—arm :: tree— SHRUB LIMB FLOWER BARK
cannon—large :: rifle— BALL SMALL BORE SHOOT
cellar—attic :: bottom— WELL TUB TOP HOUSE
bird—sing :: dog— FIRE BARK SNOW FLAG
Wednesday—week :: July— AUGUST MONTH HOT YEAR
eat—bread :: drink— WATER IRON LEAD STONE
advice—command :: persuasion— HELP AID URGING COMPULSION
father—son:: mother— AUNT NEPHEW DAUGHTER SISTER
imitate—invent :: copy— WRITE PENCIL ORIGINATE DRAW
heehaw—donkey :: bow wow— HEN CAT SPEECH DOG
character—important :: complexion— TRIVIAL BLONDE BRUNETTE GOOD
engineer—locomotive :: chauffeur— DRIVE AUTO HORSE WAGON
prosperity—happiness :: adversity— SUCCESS SORROW FUN RAGE
love—hatred :: friend— LOVER MOTHER NEED ENEMY
success—failure :: joy— PLEASURE SADNESS WORK FUN
wrist—bracelet :: neck— COLLAR LEG FOOT GIRAFFE
northpole—equator :: frigid— COAL CANADA COLD TORRID
sailor—navy :: soldier— GUN PRIVATE ARMY FIGHT
behind—late :: before— AFTER SOON EARLY DINNER
carpenter—house :: shoemaker— HATMAKER WAX SHOE LEATHER
light—dark :: noise— REPORT RING SILENCE SOUND
shoestring—shoe :: button— COAT CATCH BELL HOOK
writer—books :: bee— HIVE HONEY WASP STING

2. NUMBER SERIES COMPLETION.

SAMPLES	2	4	6	8	10	12	..14..	..16..
	9	8	7	6	5	4	...3..	...2..
	2	2	3	3	4	4	...5..	...5..
	1	7	2	7	3	7	...4..	...7..

Look at each row of numbers below, and on the two dotted lines write the two numbers that should come next.

8	8	6	6	4	4	......	......
4	8	10	20	22	44	......	......
3	7	11	15	19	23	......	......
21	18	16	15	12	10	......	......
9	1	7	1	5	1	......	......
1	4	9	16	25	36	......	......
25	25	21	21	17	17	......	......
15	16	14	17	13	18	......	......
4	5	8	9	12	13	......	......
16	8	4	2	1	1/2	......	......
21	18	16	13	11	8	......	......
16	12	15	11	14	10	......	......
1	2	4	8	16	32	......	......
25	24	22	21	19	18	......	......
3	4	6	9	13	18	......	......
12	14	13	15	14	16	......	......
6	9	12	15	18	21	......	......
3	6	8	16	18	36	......	......
8	1	6	1	4	1	......	......
16	17	15	18	14	19	......	......
8	9	12	13	16	17	......	......
81	27	9	3	1	1/3	......	......
27	27	23	23	19	19	......	......
20	17	15	14	11	9	......	......
19	16	14	11	9	6	......	......
18	14	17	13	16	12	......	......
11	13	12	14	13	15	......	......
2	3	5	8	12	17	......	......

3. CANCELLATION.

5 1 6 8 4 9 2 3 7 0 1 2 7 5 0 4 8 6 9 3 4 1 8 9 0 2 5 6 3 7 1 7 5 6 0 8 9 2 4 3 7 8 6 9 0 4 3 1 2 5
7 8 0 5 1 3 4 2 6 9 2 4 0 9 7 6 1 5 3 8 3 2 0 4 1 5 7 9 6 8 4 8 1 2 6 7 3 9 0 5 3 7 9 0 8 6 5 2 1 4
3 5 9 7 8 4 6 1 0 2 5 1 8 2 3 7 4 9 6 0 8 5 9 3 2 4 1 0 7 6 9 3 4 5 2 0 8 6 1 7 9 3 1 6 7 5 8 4 0 2
2 7 3 9 6 5 0 8 1 4 9 7 3 6 1 5 0 2 8 4 0 4 7 8 5 9 6 2 1 3 0 9 3 1 5 6 4 8 7 2 4 2 3 5 6 7 9 0 8 1
4 2 5 3 0 1 7 9 8 6 3 8 6 0 9 1 5 4 7 2 9 3 6 7 4 8 0 1 2 5 6 4 9 3 1 2 0 7 5 8 6 1 2 7 4 9 0 5 3 8
9 4 7 0 3 8 5 6 2 1 6 0 9 3 8 2 7 1 4 5 7 8 1 0 9 6 4 3 5 2 5 2 7 9 4 1 6 3 8 0 1 0 4 8 2 3 7 9 5 6
0 9 8 2 5 6 1 7 4 3 8 3 5 4 6 9 2 0 1 7 6 0 2 1 3 7 9 5 8 4 2 1 8 4 9 5 7 0 3 6 0 9 5 2 1 8 6 7 4 3
1 0 4 6 2 7 9 5 3 8 0 6 2 8 4 3 9 7 5 1 2 7 4 5 6 0 3 8 9 1 3 5 0 7 8 4 2 1 6 9 5 6 8 1 9 2 4 3 7 0
8 6 1 4 9 2 3 0 5 7 4 5 1 7 2 8 6 3 0 9 1 9 5 6 8 3 2 7 4 0 8 6 2 0 7 3 5 4 9 1 2 4 7 3 5 0 1 8 6 9
6 3 2 1 7 0 8 4 9 5 7 9 4 1 5 0 3 8 2 6 5 6 3 2 7 1 8 4 0 9 7 0 6 8 3 9 1 5 2 4 8 5 0 4 3 1 2 6 9 7
7 9 6 2 1 3 4 0 5 8 4 2 5 1 9 3 8 6 0 7 9 0 4 8 1 7 2 3 6 5 6 2 8 3 0 5 1 4 9 7 5 9 4 8 0 7 1 2 3 6
9 6 8 1 0 5 3 7 4 2 1 9 4 5 3 7 0 2 6 8 0 4 7 2 3 8 6 5 9 1 9 0 3 6 8 2 7 1 5 4 7 5 0 3 2 9 4 1 6 8
0 7 3 4 2 9 1 8 6 5 9 6 1 2 4 8 7 0 5 3 1 9 8 3 0 6 5 4 7 2 1 5 7 9 3 4 8 2 6 0 8 3 5 9 7 2 6 4 0 1
3 4 7 6 8 1 2 5 9 0 6 3 0 7 5 9 4 8 1 2 4 8 5 9 7 3 1 2 0 6 7 1 0 2 9 6 4 5 3 8 3 4 7 1 6 5 2 8 9 0
6 5 9 7 3 2 8 4 0 1 0 8 3 6 1 4 9 7 2 5 2 5 3 4 6 9 0 1 8 7 5 4 1 7 2 8 3 9 0 6 1 2 6 5 8 3 0 7 4 9
8 3 5 0 9 4 7 2 1 6 8 5 7 0 2 1 3 9 4 6 5 2 1 0 8 4 7 6 3 9 2 7 4 5 1 9 0 6 8 3 6 8 9 7 1 0 3 5 2 4
1 8 0 9 7 6 5 3 2 4 2 7 8 4 6 5 1 3 9 0 3 1 2 6 9 5 8 7 4 0 4 8 2 0 5 1 6 3 7 9 4 1 8 0 5 6 9 3 7 2
2 0 4 8 5 7 6 1 3 9 7 1 6 8 0 2 5 4 3 9 6 7 0 1 4 2 3 9 5 8 0 6 9 4 7 3 2 8 1 5 2 0 1 6 4 8 7 9 5 3
4 1 2 5 6 8 0 9 7 3 5 0 9 3 7 6 2 1 8 4 8 6 9 7 5 1 4 0 2 3 8 3 5 1 6 7 9 0 4 2 9 6 2 4 3 1 5 0 8 7
5 2 1 3 4 0 9 6 8 7 3 4 2 9 8 0 6 5 7 1 7 3 6 5 2 0 9 8 1 4 3 9 6 8 4 0 5 7 2 1 0 7 3 2 9 4 8 6 1 5

4. CONSTANT INCREMENT.

64	72
49	35
62	51
57	30
68	56
74	44
53	36
67	73
25	63
40	47
61	43
71	66
33	69
38	37
28	39
65	32
41	59
50	31
42	60
58	48
52	54
70	46
26	55
34	27
45	29

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